Blood and Vascular Anatomy

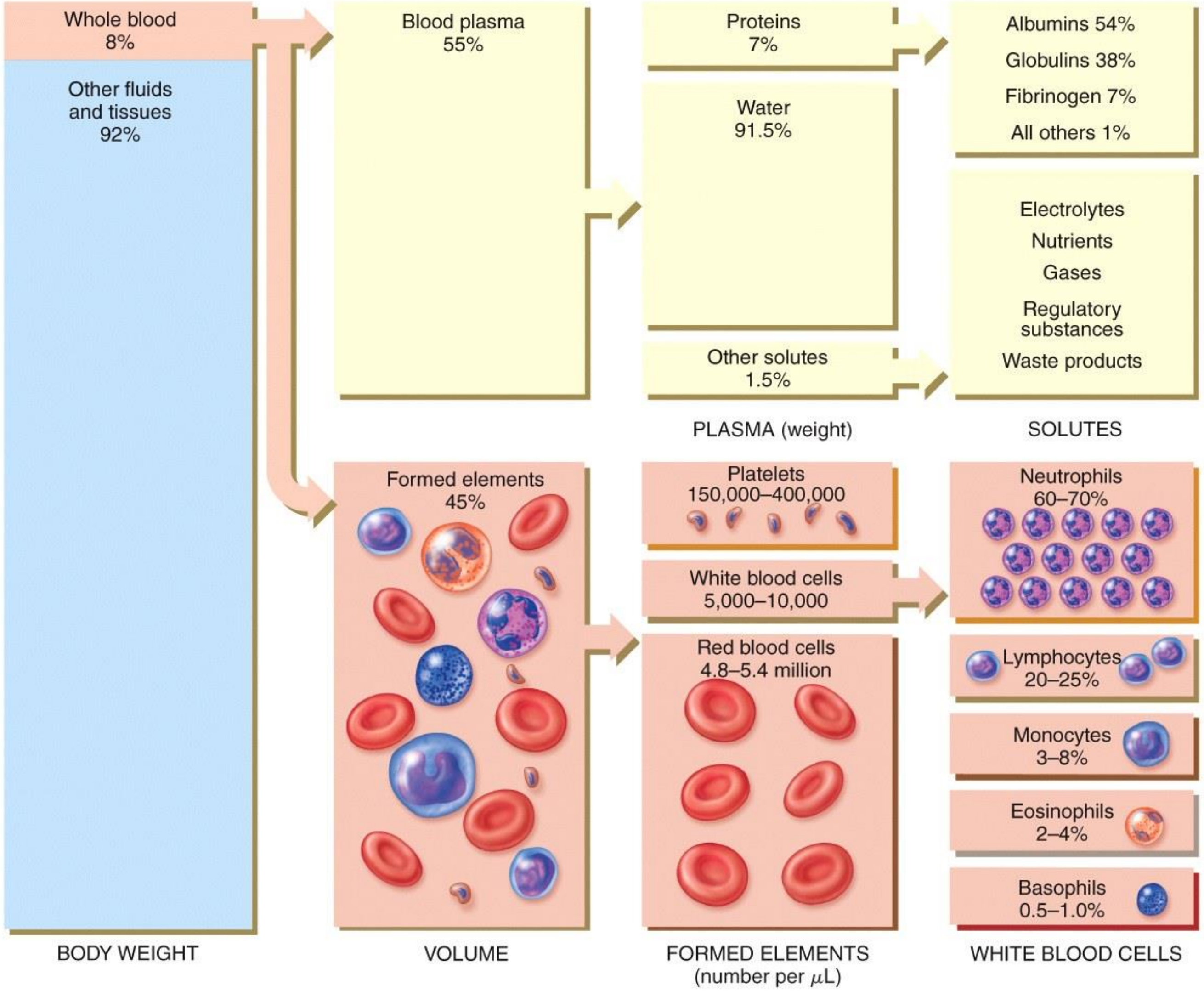
Primary Care Paramedicine

Module:12
Section:01

Blood and Vascular Anatomy

BLOOD

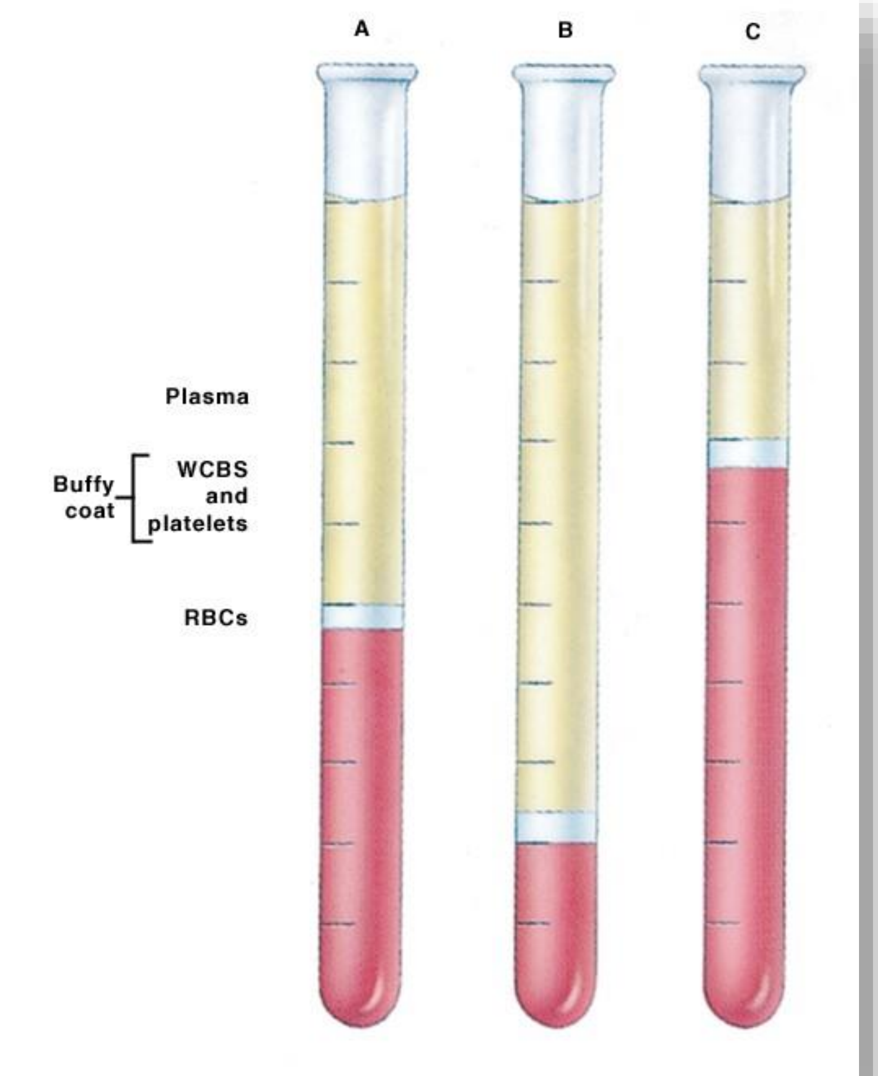
Constituents of Blood



(b) Components of blood

The Blood

- Hematocrit
  - A Normal
    - Male 40 – 54%
    - Female 38 – 47%
  - B Anemia
    - Decrease in RBC
  - C Polycythemia
    - High altitudes

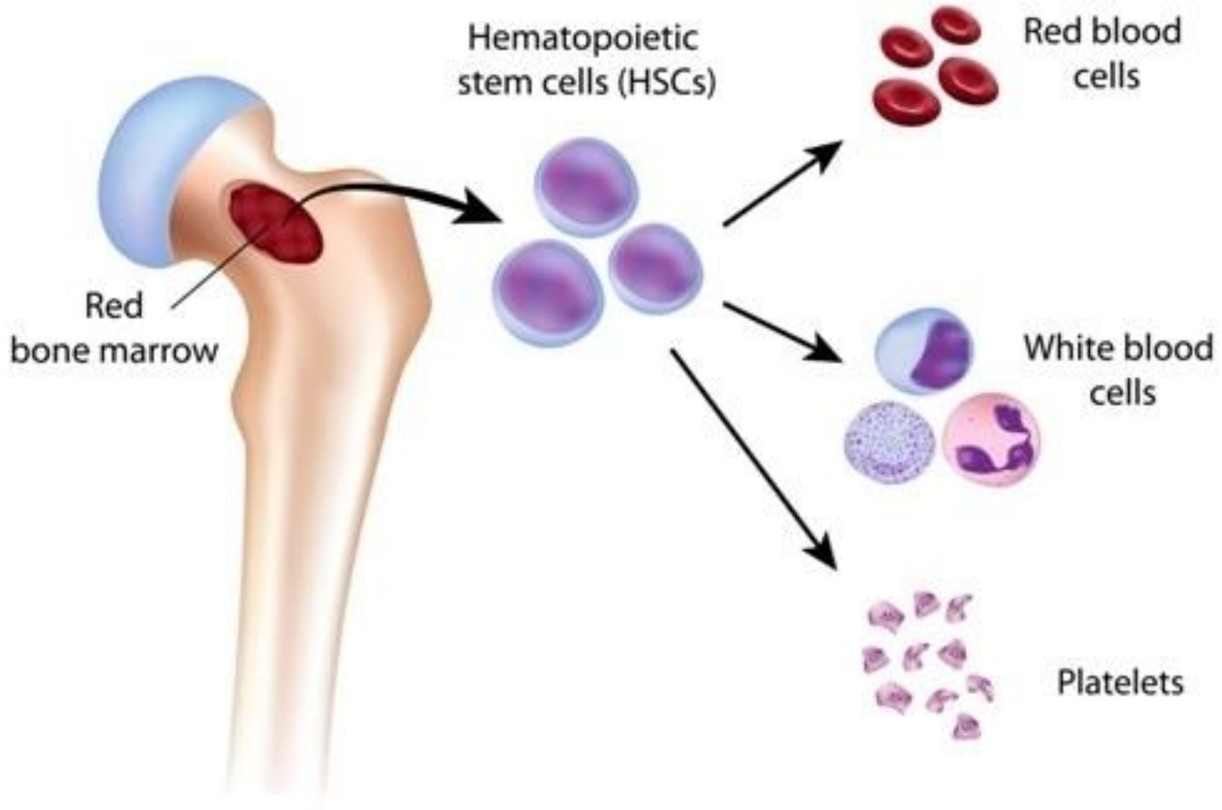


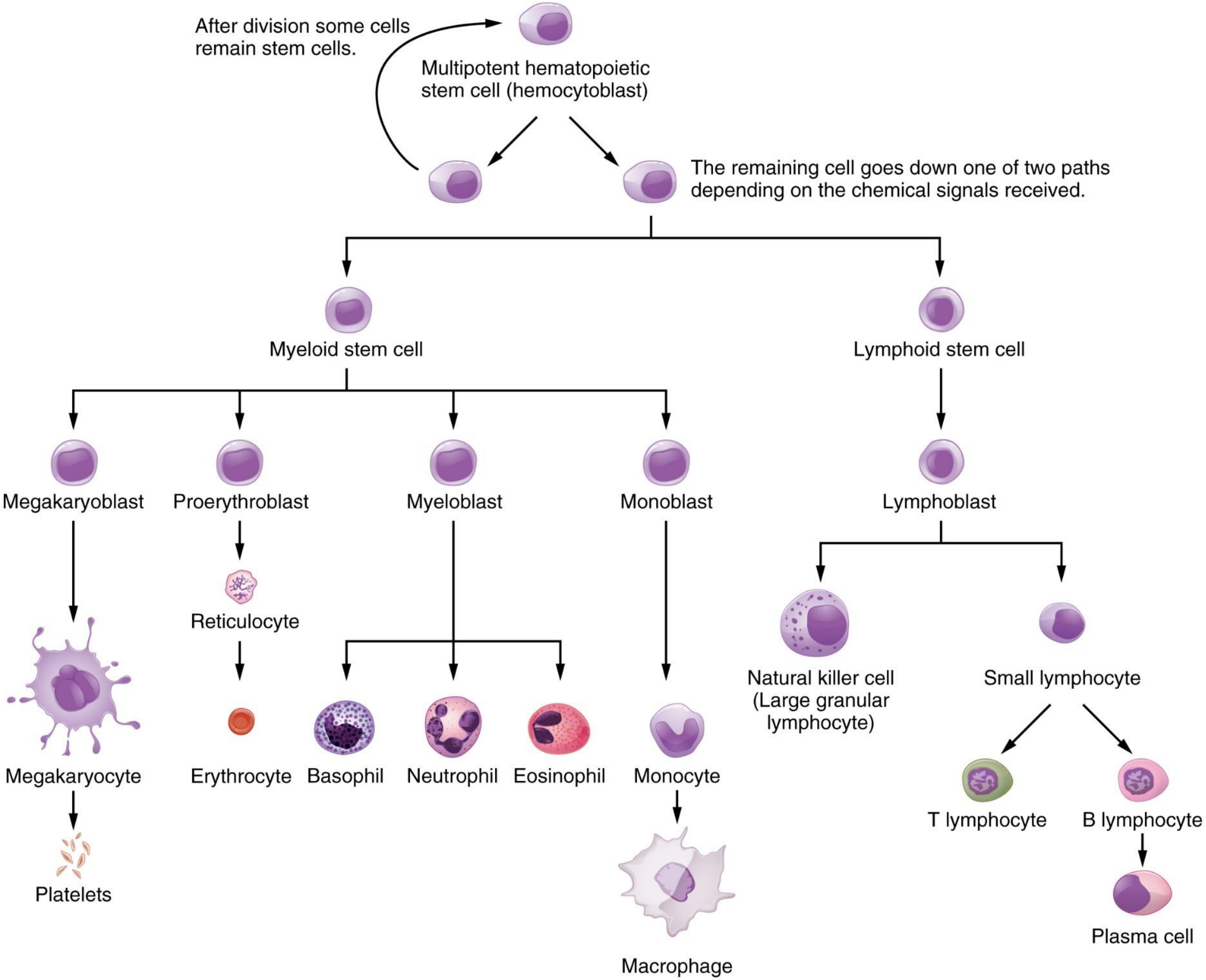
The Blood

- Formed elements
  - All elements are formed from a hemocytoblast
  - The formation of the elements is called hematopoiesis
  - 3 main types
    - Erythrocytes
    - Leukocytes
    - Thrombocytes

Hematopoiesis

- The process by which the formed elements of blood develop is called hemopoiesis (hematopoiesis).
- In adults, blood cells are formed in red bone marrow from pluripotent stem cells.
- They mature in bone marrow or lymphoid tissue.



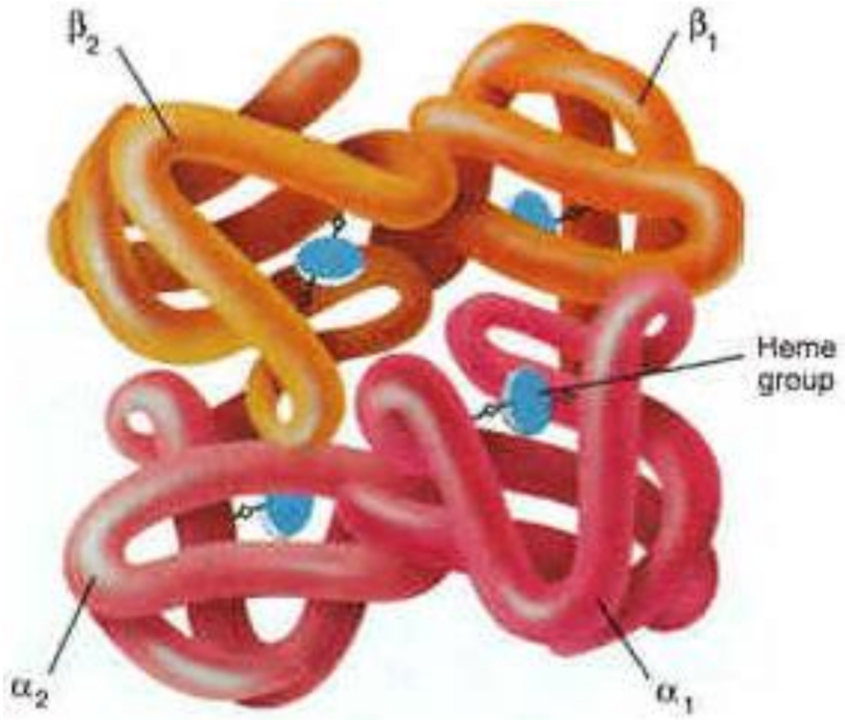

After division some cells remain stem cells.
Multipotent hematopoietic stem cell (hemocytoblast)
The remaining cell goes down one of two paths depending on the chemical signals received.
Myeloid stem cell
Lymphoid stem cell
Megakaryoblast
Proerythroblast
Myeloblast
Monoblast
Lymphoblast
Reticulocyte
Natural killer cell (Large granular lymphocyte)
Small lymphocyte
Megakaryocyte
Erythrocyte
Basophil
Neutrophil
Eosinophil
Monocyte
T lymphocyte
B lymphocyte
Platelets
Plasma cell
Macrophage

Erythrocytes

- The most abundant (4.5 – 6 million/mm^3)
- Biconcave discs
- Mature cells are anucleate
  - Mature cells cannot enter mitosis so new cells are created from stem cells
- Immature cells move from bone marrow to the blood (are called reticulocytes)
- Also contain spectrin fibers which are part of the cytoskeleton and give it flexibility

Erythrocytes

- Found inside each RBC is an estimated 200 – 300 million hemoglobin molecules
- Consists of 4 protein chains (globin) which are bound together by heme groups
- Each heme group contains an iron atom (4 in total)
- This allows the hemoglobin to attach to 4 oxygen molecules or 4 carbon dioxide molecules



Erythrocytes

- Primary function to transport O_2 and CO_2
- Directly related to:
  - Hemoglobin
    - Oxyhemoglobin (97% of transport)
    - Deoxyhemoglobin when O_2 released (darker in color)
  - Carbonic anhydrase
    - Causes the conversion of CO_2 and water into bicarbonate (or reverse)

Erythrocytes

- Production (Erythropoiesis)
  - Produce from stem cells which divide through several stages to reach the mature blood cell into the blood stream
  - Usually an equal number produced as is destroyed
    - Estimated 200 billion per minute produced

Erythrocytes

- Oxygen factor
  - If oxygen levels reaching the tissue decreases then it stimulates the release of erythropoietinogen
  - Kidneys produce and release renal erythropoietic factor (REF)
  - Activates erythropoietinogen to form erythropoietin to stimulate red bone marrow to produce RBC's
- Iron, vitamin B12 and folic acid are essential to normal RBC production

Erythrocytes

- Destruction
  - Normal cells live for about 120 days
  - When they are defective or worn out macrophages in spleen and liver remove them
  - Hemoglobin is broken down and reuses heme for production (is broken into iron and bilirubin) and sends the iron to the bone marrow and bilirubin is excreted into the bile of the liver

Leukocytes

- Usually larger than RBC's but are fewer in # (5,000 - 9,000/mm3)
  - Formed in the lymphatic system (agranulocytes) and in the red bone marrow (granulocytes)
  - Also derived from hemocytoblast stem cells but do not lose nuclei or accumulate hemoglobin (why they appear white)
- Do most of their work in the tissues
- They can be phagocytic, produce antibodies, secrete histamine and heparin while others neutralize histamine

Types of Leukocytes

- Granulocytes
  - Neutrophils
    - Most common (60 - 70 %), have multi-lobed nuclei
    - Can move from blood vessels to enter tissue spaces (diapedesis)
    - First to respond to tissue damage where they engulf bacteria (phagocytosis)
    - Destroy bacteria, antigen-antibody complexes, and foreign matter

Types of Leukocytes

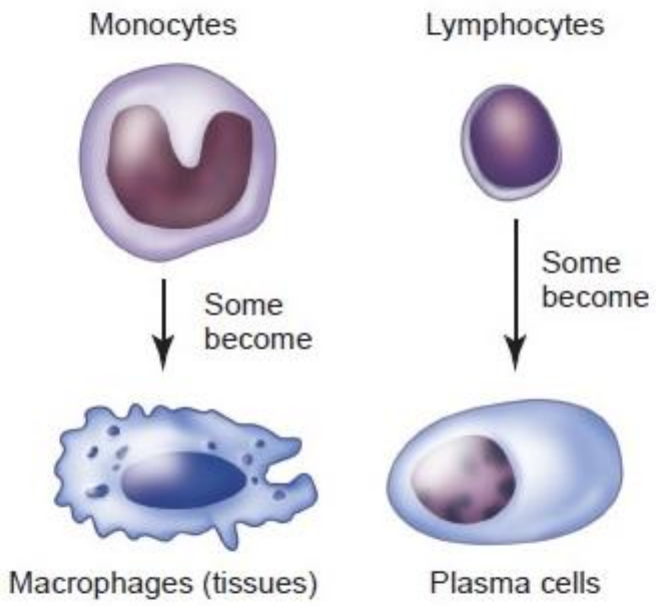
- Granulocytes
  - Eosinophils
    - 2 - 5% with 2 lobed nucleus
    - Found in respiratory and digestive tracts
    - Neutralize histamine and destroy parasitic worms
    - Increase in # during allergic reaction

Types of Leukocytes

- Granulocytes
  - Basophils
    - Least numerous (1%), U shaped nuclei
    - Capable of diapedesis
    - When they leave the blood and enter the tissue they are considered Mast Cells
    - There they secret histamine (dilates vessels) and heparin (anticoagulant)

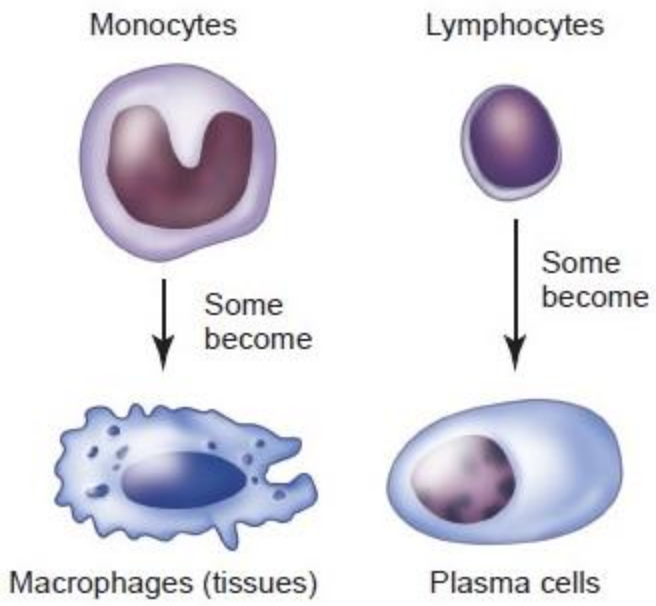
Types of Leukocytes

- Agranulocytes
  - Monocytes
    - 3-8%, U or bean shaped nuclei
    - When they leave the blood and enter the tissue the are called macrophages
    - Capable of engulfing bacteria and virus infected cells
    - Finish the clean-up of cellular debris initially started by the neutrophils
    - One of the first lines of defense in the inflammatory process



Types of Leukocytes

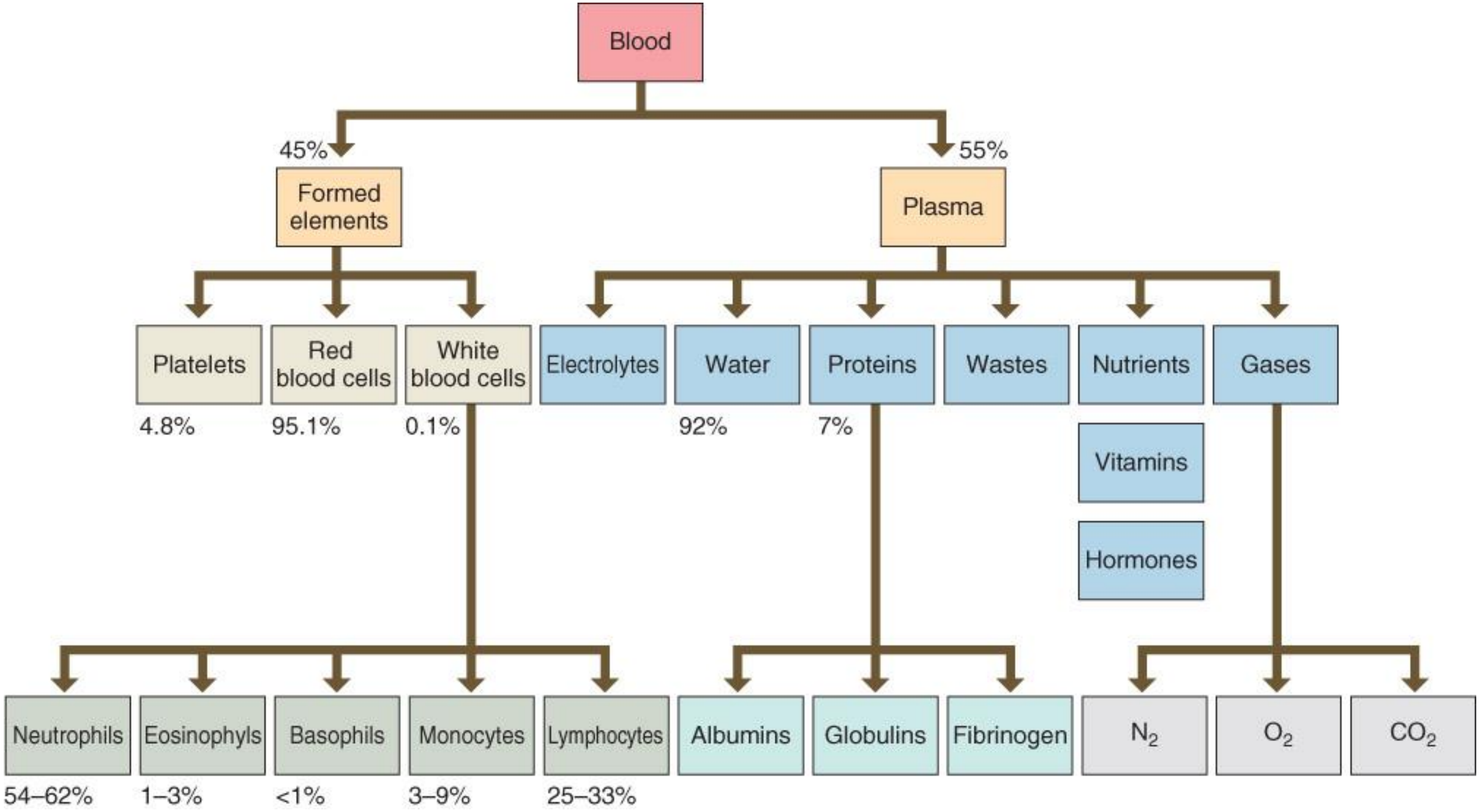
- Agranulocytes
  - Lymphocytes
    - 20 - 25%, spherical shaped nuclei
    - Important in defense
    - Originate in the bone marrow but migrate through the blood to the lymphatic tissues
      - T Cells attack bacteria and viruses
      - B Cells produce antibodies



Leukocytes

- Leukocytosis
  - Increase in the number of WBC's
  - Appendicitis
- Leukopenia
  - Decrease in the number of WBC's
  - Result of infection, or congenital
- Leukemia
  - Cancer of the lymph glands and bone marrow resulting in overproduction of white blood cells

Blood Composition



Thrombocytes (Platelets)

- Not complete cells, actually parts of megakaryocytes from the red bone marrow
- 250,000 - 500,000/mm^3
- Properties
  - Agglutination
  - Adhesiveness
  - Aggregation
  - Become sticky and clump to form platelet plugs

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Thrombocytes (Platelets)

- Thrombocytopenia
  - A decrease in the number of platelets in the blood, resulting in the potential for increased bleeding and decreased ability for clotting
  - Side effect of chemotherapy (immune response), some drugs may cause decrease, Idiopathic thrombocytopenic purpura (ITP)
- Thrombocytosis
  - An increase in the number of platelets in the blood
  - Can be as a result of:
    - Splenectomy, following acute hemorrhage, rheumatoid arthritis, infections and even a malignancy

Plasma Proteins

- Most abundant of solutes
- Remain in blood or interstitial fluid and are not used for energy
- 3 major classes
  - Albumins
  - Globulins
  - Fibrinogens

Plasma Proteins

- Albumins
  - Account for 60% of proteins
  - Attribute to osmotic pressure
- Globulins
  - Account for 36%
  - Alpha and Beta
    - Produced in liver and transport lipids and vitamins
  - Gamma
    - Produced in lymphoid tissue and are antibodies

Plasma Proteins

- Fibrinogen
  - Account for 4%
  - Largest of the molecules
  - Produced in liver
  - Functions in clotting

Hemostasis

"The stoppage of bleeding"

- Occurs with:
  - Vasoconstriction
  - Platelet plug formation
  - Coagulation

Hemostasis

- Vasoconstriction
  - Restricts flow of blood through vessels by constricting (spasms)
- Platelet plug formation
  - Platelets attracted to the collagen in the connective tissue
  - As they accumulate they release serotonin (stimulates smooth muscles to contract)
  - This prolongs vasoconstriction

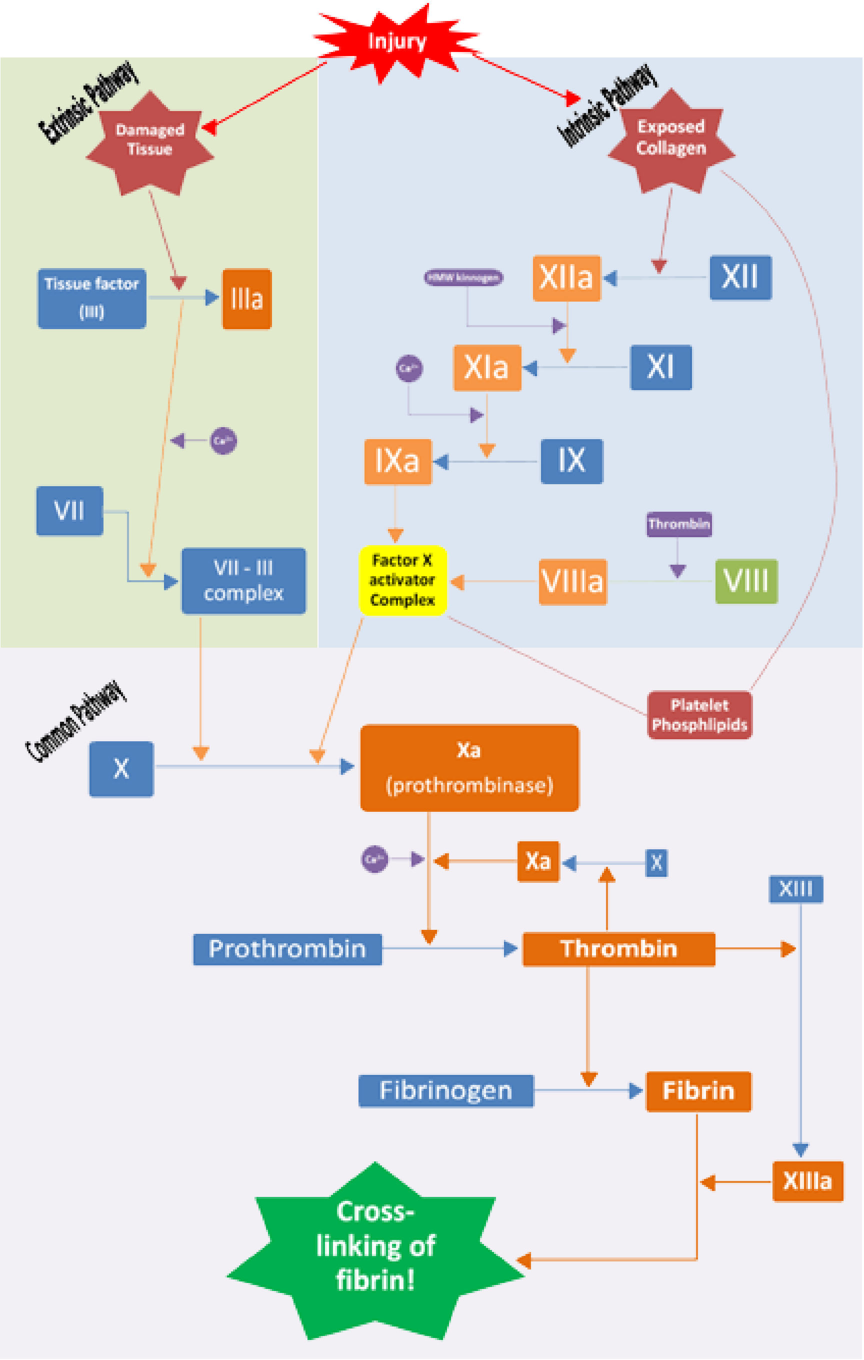
Hemostasis

- Coagulation
  - Blood contains procoagulants and anticoagulants
  - Anticoagulants predominate typically to maintain blood as a fluid
  - In an injury, procoagulants increase in activity
  - Chemical reactions and the use of clotting factors aid in the plug formation
  - Ca and Vitamin K are important in the process

Hemostasis (the process)

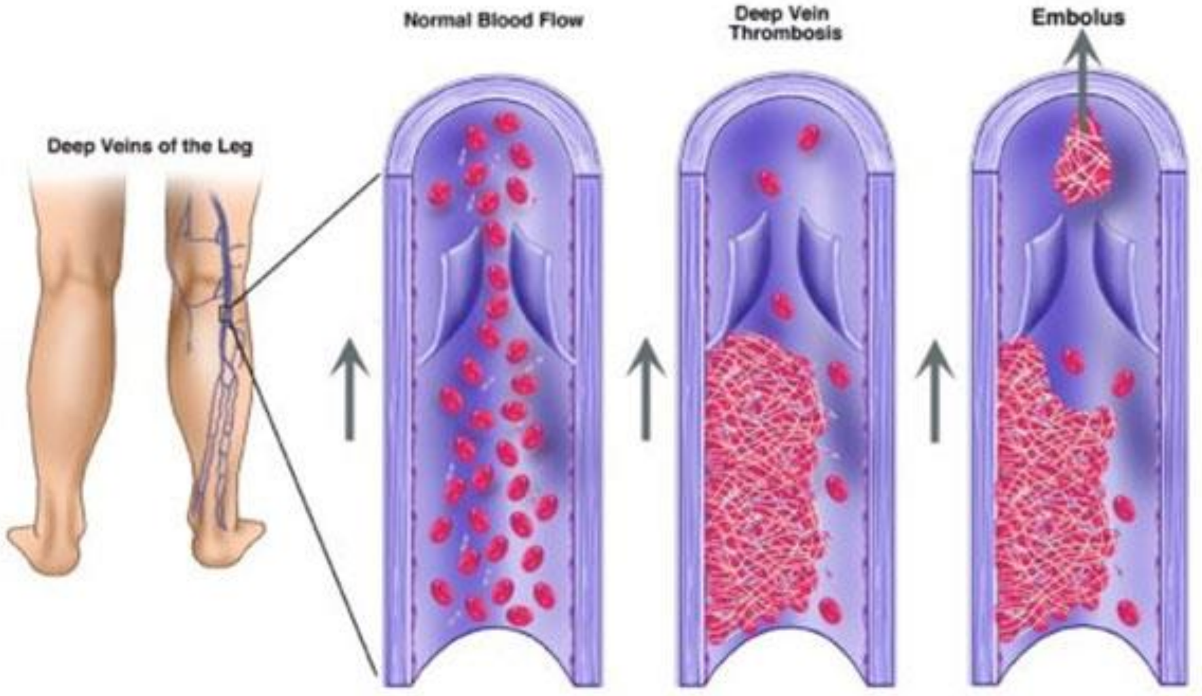
- Damaged tissue release chemicals
- This triggers a cascade of reactions involving Coagulation Factors that result in the formation of prothrombin activator (PA)
- With Ca and PA, prothrombin in the plasma is converted to active thrombin (which is normally inactive)
- Thrombin with Ca acts as an enzyme to convert inactive soluble fibrinogen into an active non-soluble fibrin
- This begins to form fibers to trap blood cells

Clotting Cascade



Hemostasis (the process)

- Embolus
  - The formation of a clot from platelets or leukocytes
- Thrombus
  - An aggregation of blood factors, primarily platelets and fibrin with entrapment of cellular elements



Hemostasis

- Increase Hemostasis
  - Apply rough surface (gauze)
  - Apply heat
  - Pinch the area around the wound (pressure)
- Decrease Hemostasis
  - Natural design of vessels
  - Presence of antithrombin (Heparin)
  - Coumarin compounds
    - Impair liver's ability to use Vitamin K which slows synthesis of prothrombin and other factors

Deteriorating the Clot

- Fibrin strands contract (clot retraction)
- Causes clot to shrink
- Pulls edges of damaged tissue together
- Reduces blood flow, reduces chances of infection and enhances healing
- Fibroblasts migrate to the clot and form fibrous connective tissue that repairs the damage
- Clot is dissolved by fibrinolysis

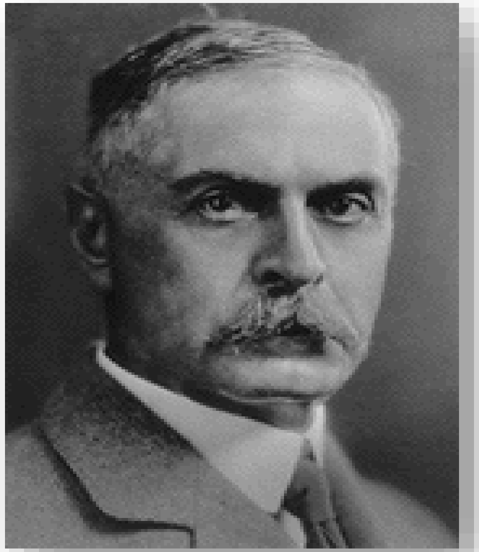
Blood and Vascular Anatomy

BLOOD TYPING

Blood Typing

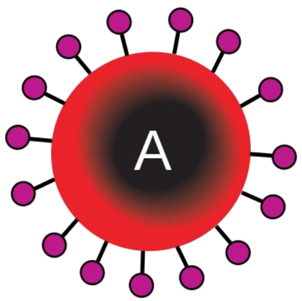
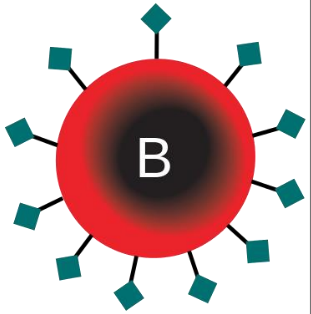
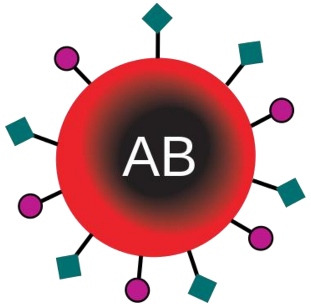
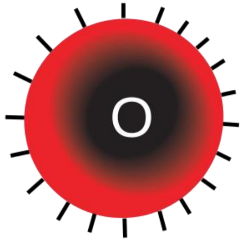
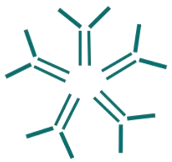
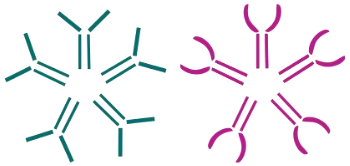
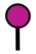
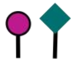
- Blood type is based on specific proteins (antigens) and antibodies related to RBC's
- Antigens (agglutinogens) for blood type are found in the cell membrane of the RBC
- Antibodies (agglutinins) are found in the plasma
- When they combine they result in agglutination
- Though there are many groups, ABO and Rh groups are the most important

ABO System



- Discovered by Dr. Karl Landsteiner in 1901
- His experiment involved mixing the serum and RBC's of patients and observing the reactions
- Noted 3 distinct groups
  - A, B and C (C was later changed to O)
- In 1902 Decastello and Sturli identified the fourth group which was labeled as AB

Blood Types

	Group A	Group B	Group AB	Group O
Red blood cell type				
Antibodies in Plasma	 Anti-B	 Anti-A	None	 Anti-A and Anti-B
Antigens in Red Blood Cell	 A antigen	 B antigen	 A and B antigens	None

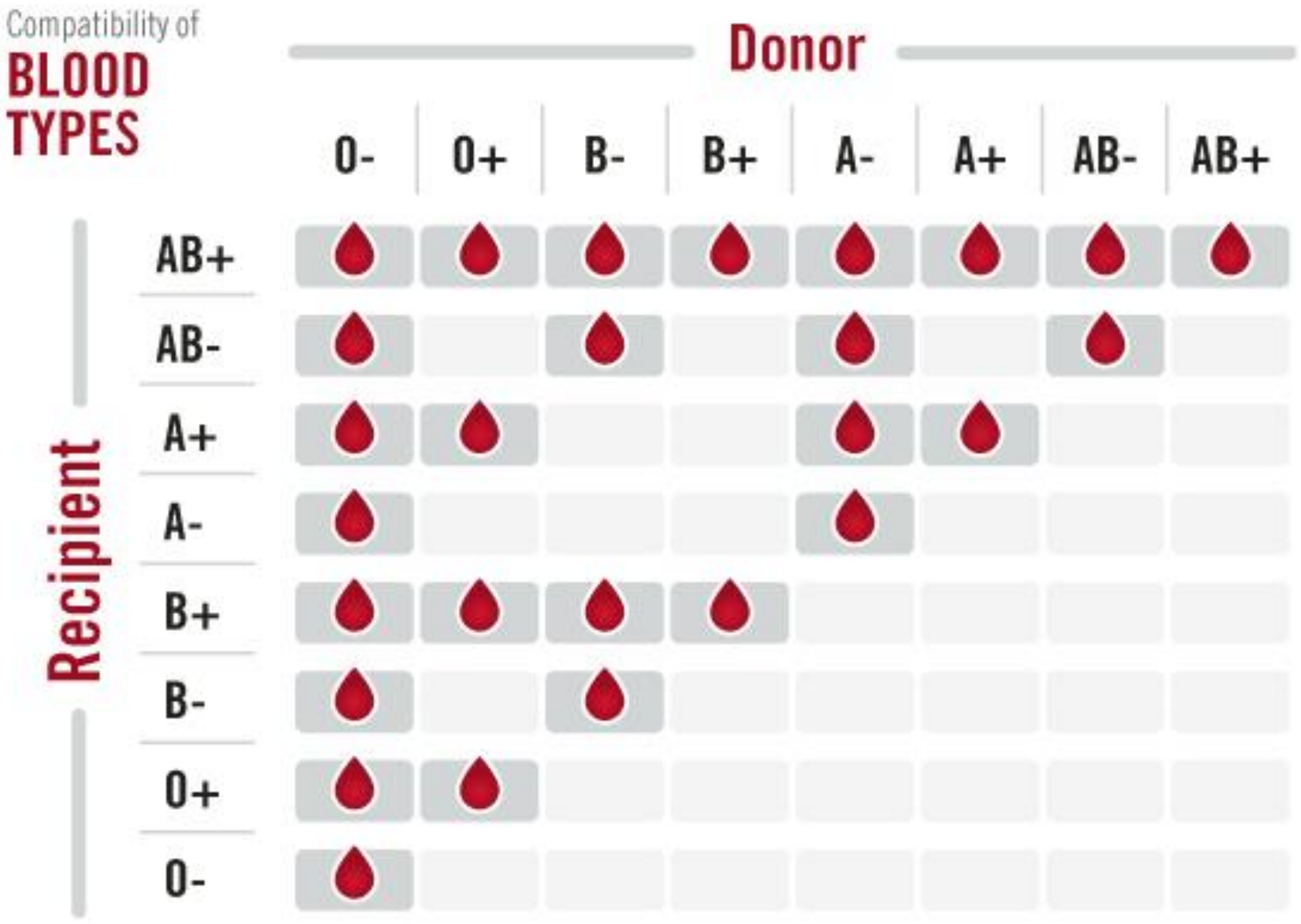
ABO System

- The fact that the ABO blood group system was inherited was suggested in 1910 by Epstein and Ottenberg and confirmed by Von Dungern and Hirszfeld.
- They studied 72 families with 102 children.
- Found the ABO gene was autosomal (the gene was not on either sex chromosome)
- Therefore each person has two copies of genes coding for their ABO blood group (one maternal and one paternal in origin)
- A and B are dominant over the O
- Also found that the A and B were co-dominant

ABO Group

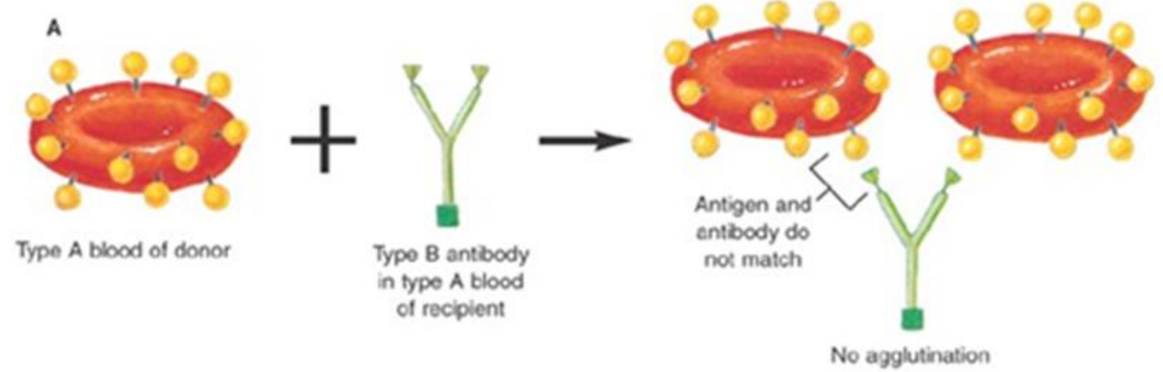
- Based on certain agglutinogens (A & B antigens)
  - Type O has none, Type A has A, Type B has B
- Is inherited
- Develop anti-agglutinins based on the antigens
  - Type A has anti-B, Type B has anti-A, Type O has Anti-AB
- Type AB is known as the Universal Recipient
- Type O is known as the Universal Donor

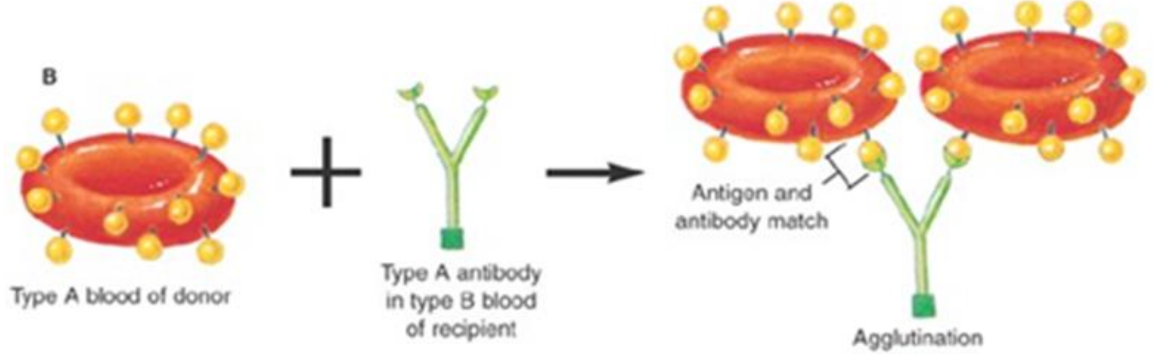
The Blood


Compatibility of
BLOOD TYPES
Donor
0-
0+
B-
B+
A-
A+
AB-
AB+
Recipient
AB+
AB-
A+
A-
B+
B-
0+
0-

The Blood

- Blood Typing
  - A
    - Proper match of blood product results in no agglutination
  - B
    - Poor match, antigen-antibody complex formed and agglutination occurs





Rh Factor

- Rh Factor
  - Rh^+
    - Rh agglutinogens are on the surface of the RBC (85% of population)
  - Rh^-
    - Rh agglutinogens are not present
  - Also inherited
  - Normally no anti-Rh agglutinins found
    - If Rh- is exposed to Rh^+ blood then anti-Rh agglutinins are formed
    - Reaction occurs with second exposure

Blood and Vascular Anatomy

VASCULAR ANATOMY

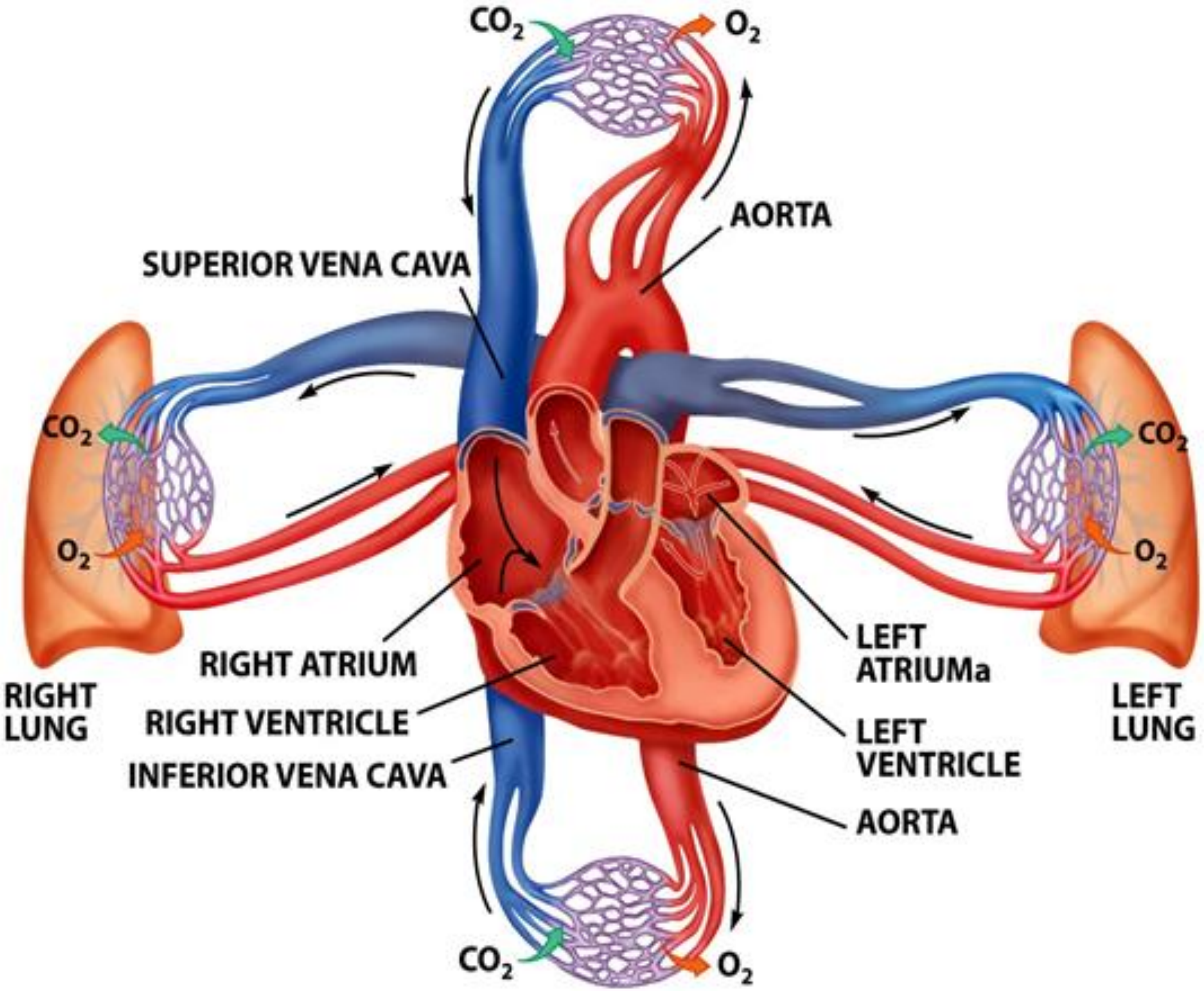
Objectives

- Understand the historical progression of knowledge regarding the components and function of the cardiovascular system.
- Identify the blood vessels of the body used for intravenous cannulation and phlebotomy.
- Recognize the anatomical components of the vasculature.

The Vessels

- Are the channels where blood is distributed throughout the body to the tissues
- Make up the two closed systems
  - Pulmonary Vessels
  - Systemic Vessels
- Are classified as:
  - Arteries
  - Capillaries
  - Veins

The Vessels



CO_2
O_2
AORTA
SUPERIOR VENA CAVA
CO_2
O_2
CO_2
O_2
RIGHT ATRIUM
RIGHT LUNG
RIGHT VENTRICLE
INFERIOR VENA CAVA
LEFT ATRIUMa
LEFT VENTRICLE
AORTA
LEFT LUNG
CO_2
O_2

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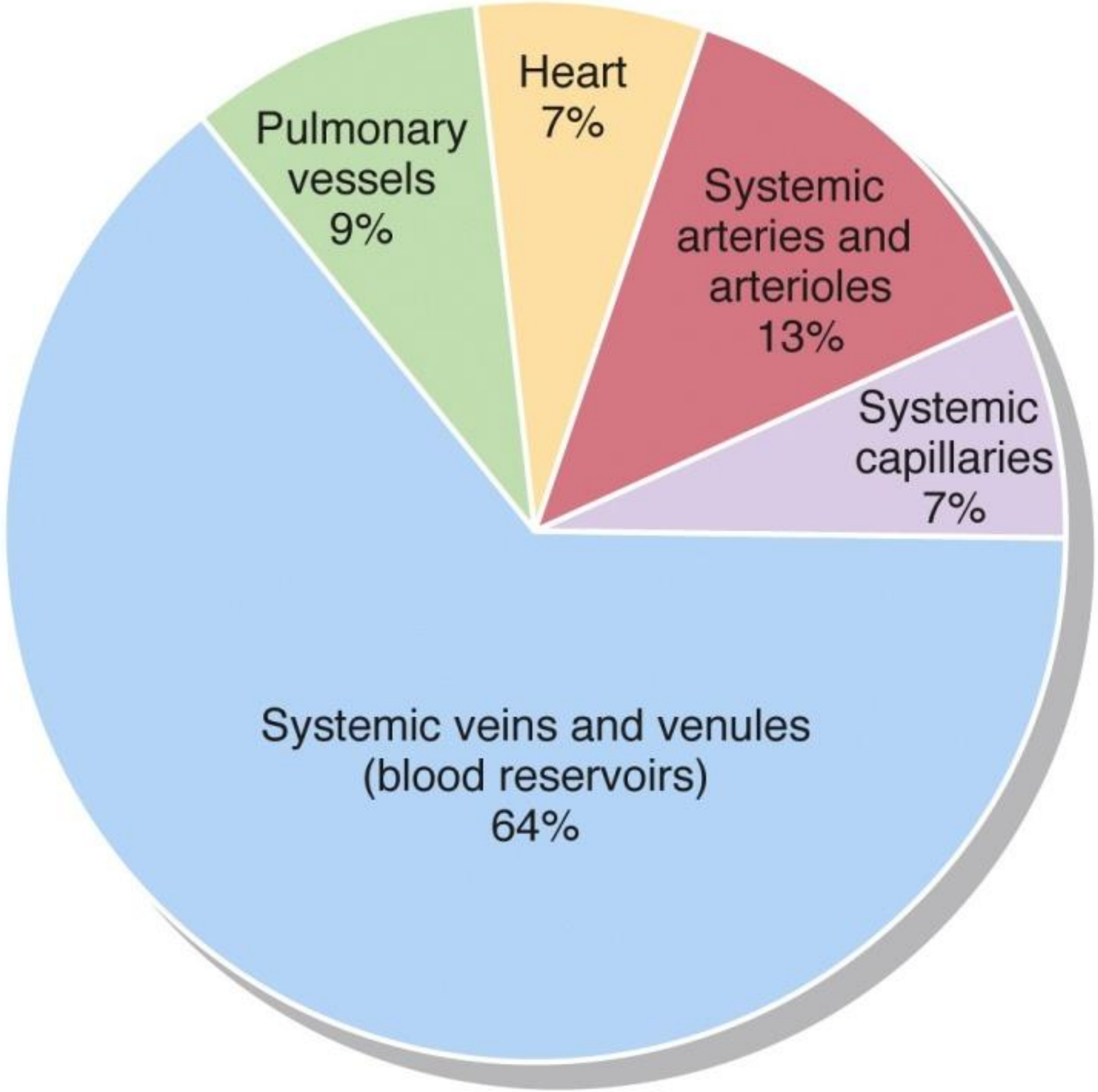
Vessel Structure and Function

- Blood Vessel Types
  - Arteries
    - Carry blood away from the heart
  - Capillaries
    - Site of nutrient and gas exchange
  - Veins
    - Carry blood towards the heart



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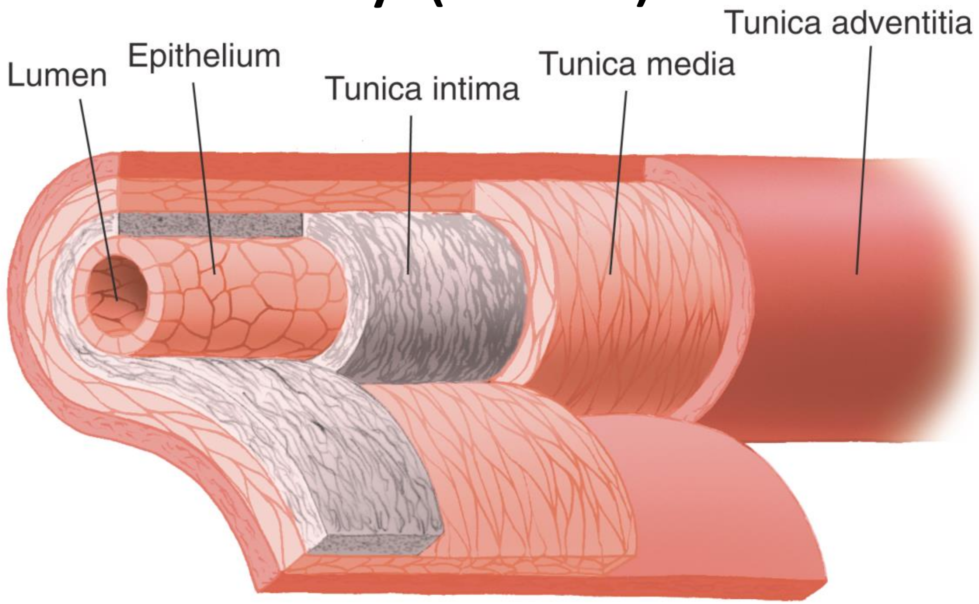
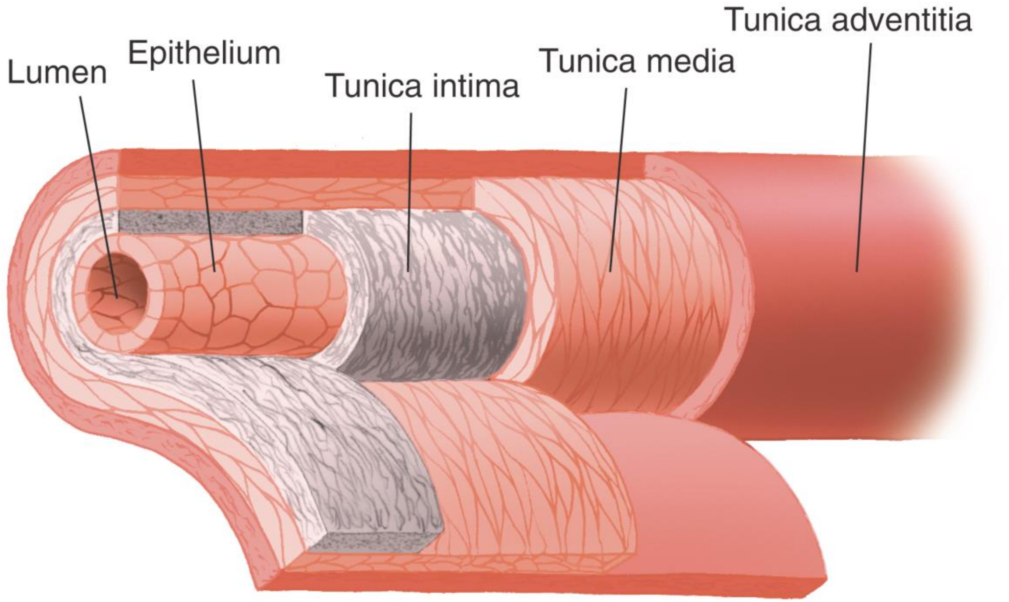
Arteries

- Carry blood away from the heart
- Typically contains oxygenated blood
- Have about 10% of total volume
- Range in size from the largest artery in the body (aorta) to the tiniest arterial branch (arteriole)



Arteries

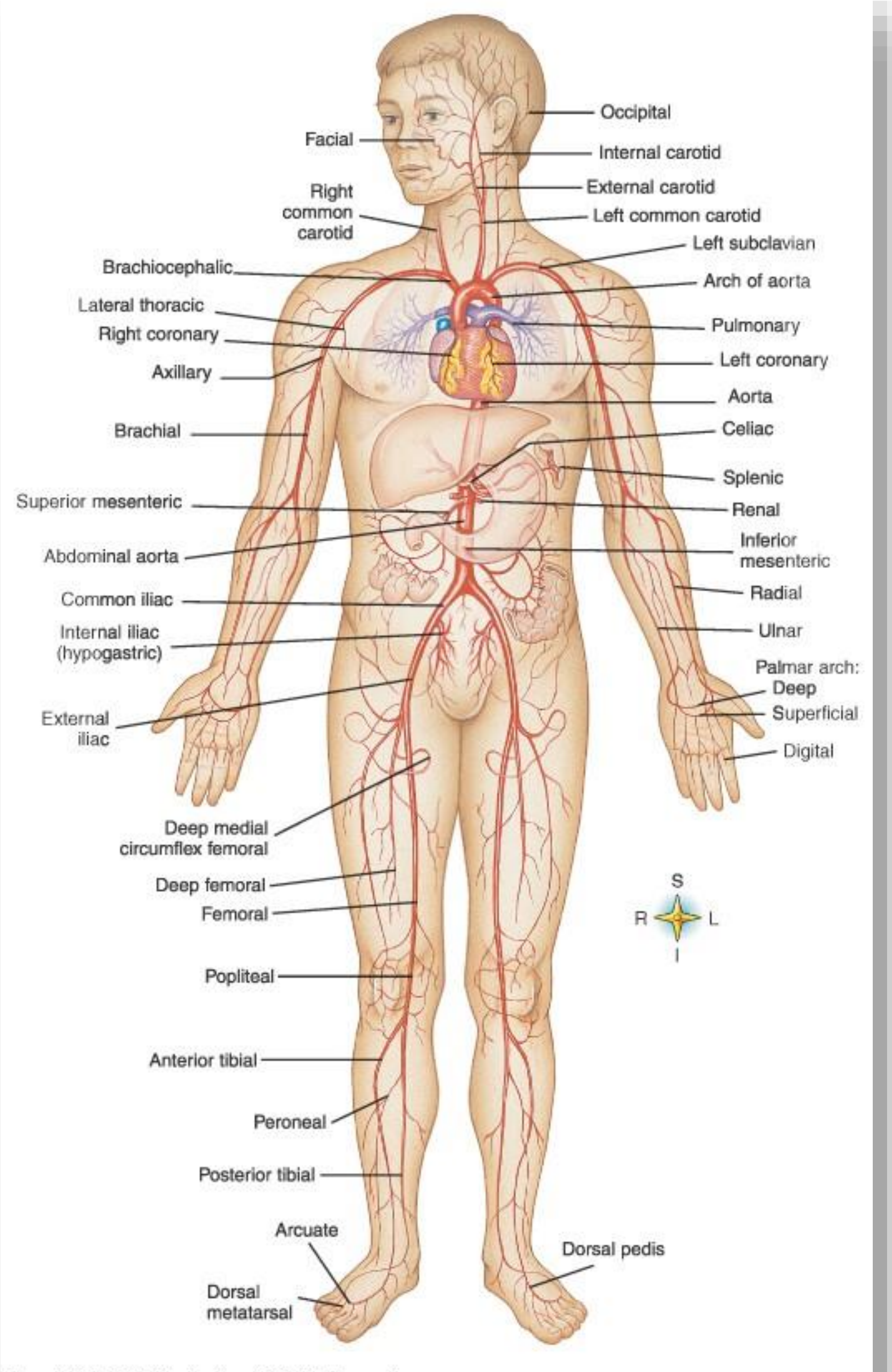
- Highly sensitive to stimulation from the autonomic nervous system
- Diameter may change significantly as they contract and relax.
- Regulate blood pressure (BP) generated by blood flowing through the body



Arteries

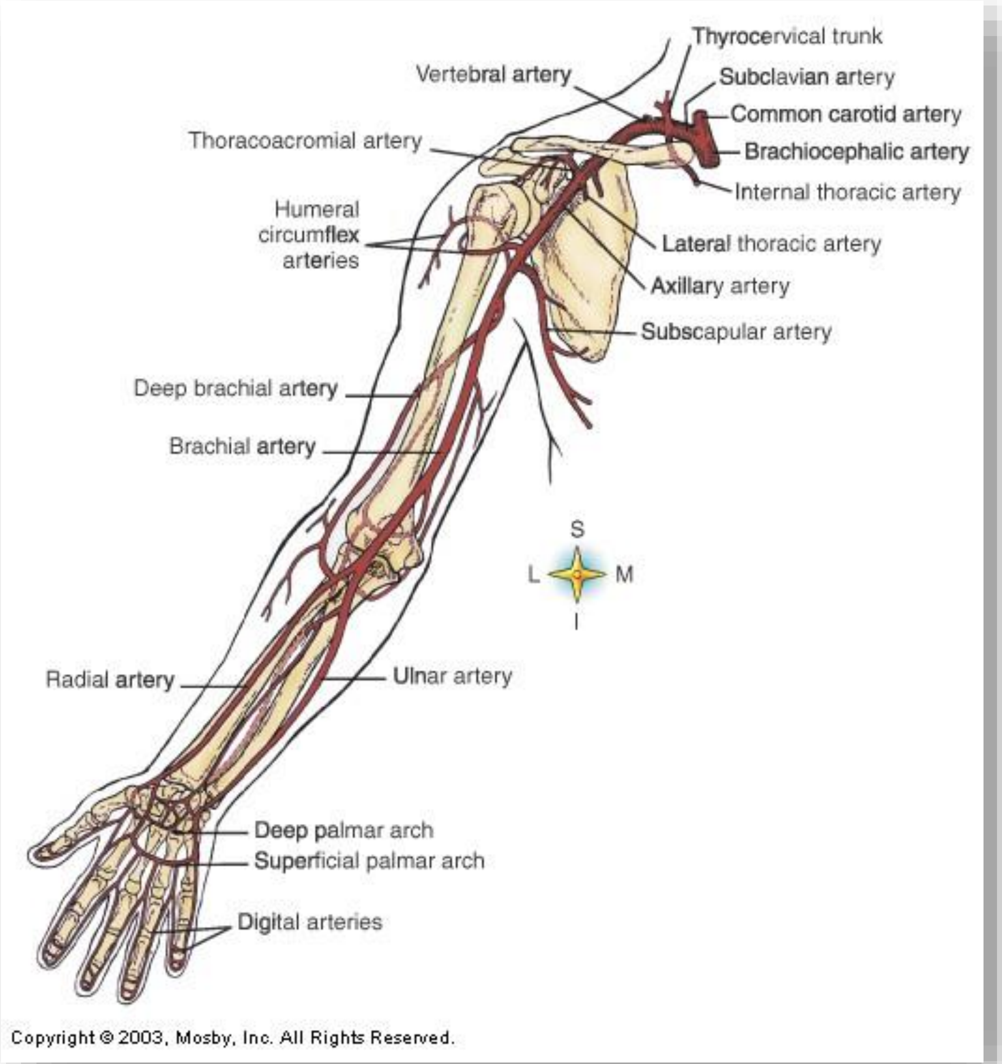
- Composed of three layers
  - Inner
    - Tunica Intima (tunica interna)
    - Continuous smooth lining of endothelium cells
  - Middle
    - Tunica Media (THICKEST)
    - Smooth muscle layer
  - Outer
    - Tunica Externa (tunica adventitia)
    - Strong flexible tissue which helps hold the vessel open and prevents tearing during movement
    - Contain Vasa Vasorum that provide blood supply to the vessel

Arteries



Occipital
Facial
Internal carotid
External carotid
Right common carotid
Left common carotid
Left subclavian
Brachiocephalic
Arch of aorta
Lateral thoracic
Pulmonary
Right coronary
Left coronary
Axillary
Aorta
Brachial
Celiac
Splenic
Superior mesenteric
Renal
Inferior mesenteric
Abdominal aorta
Radial
Common iliac
Ulnar
Internal iliac (hypogastric)
Palmar arch:
Deep
Superficial
External iliac
Digital
Deep medial circumflex femoral
S
R
L
I
Deep femoral
Femoral
Popliteal
Anterior tibial
Peroneal
Posterior tibial
Arcuate
Dorsal pedis
Dorsal metatarsal

Arteries


Thyrocervical trunk
Vertebral artery
Subclavian artery
Common carotid artery
Thoracoacromial artery
Brachiocephalic artery
Internal thoracic artery
Humeral circumflex arteries
Lateral thoracic artery
Axillary artery
Subscapular artery
Deep brachial artery
Brachial artery
S
L
M
I
Radial artery
Ulnar artery
Deep palmar arch
Superficial palmar arch
Digital arteries
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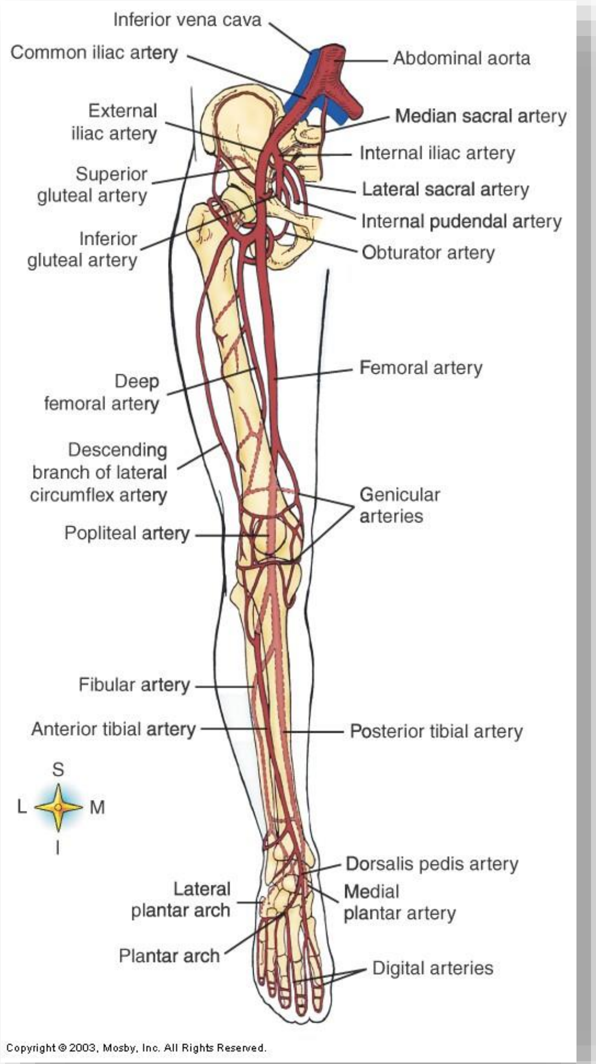
Inferior vena cava
Common iliac artery
Abdominal aorta
External iliac artery
Median sacral artery
Internal iliac artery
Superior gluteal artery
Lateral sacral artery
Internal pudendal artery
Inferior gluteal artery
Obturator artery
Femoral artery
Deep femoral artery
Descending branch of lateral circumflex artery
Genicular arteries
Popliteal artery
Fibular artery
Anterior tibial artery
Posterior tibial artery
S
L
M
I
Dorsalis pedis artery
Lateral plantar arch
Medial plantar artery
Plantar arch
Digital arteries
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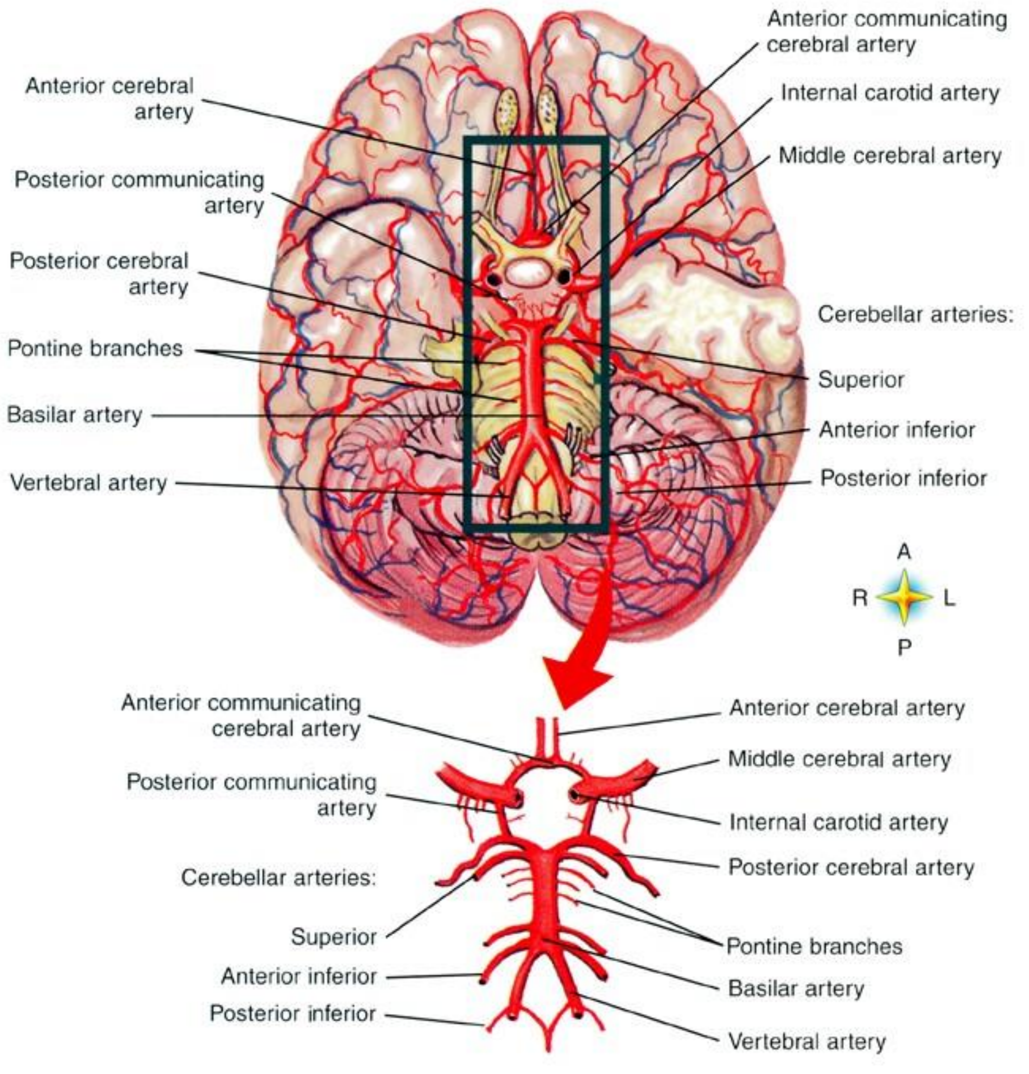
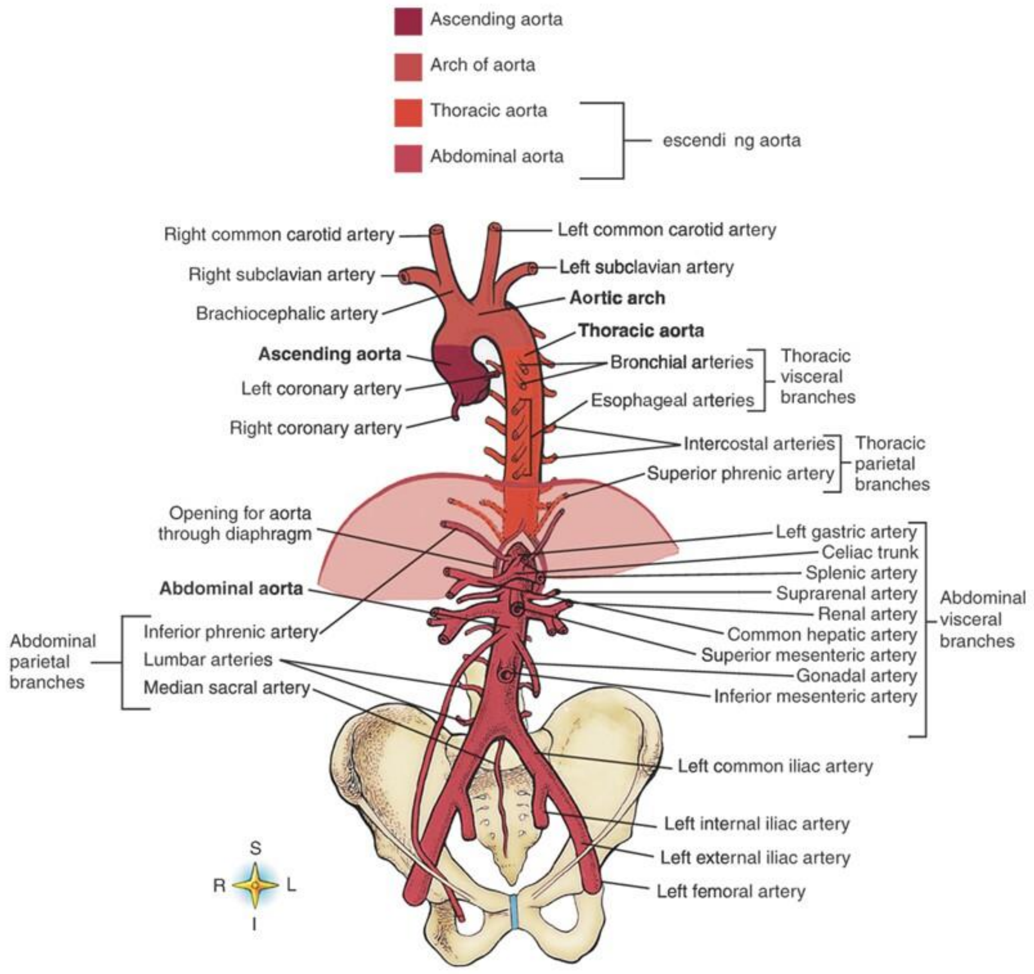
Arteries



Anterior cerebral artery
Posterior communicating artery
Posterior cerebral artery
Pontine branches
Basilar artery
Vertebral artery
Anterior communicating cerebral artery
Internal carotid artery
Middle cerebral artery
Cerebellar arteries:
Superior
Anterior inferior
Posterior inferior
A
R
L
P
Anterior communicating cerebral artery
Posterior communicating artery
Cerebellar arteries:
Superior
Anterior inferior
Posterior inferior
Anterior cerebral artery
Middle cerebral artery
Internal carotid artery
Posterior cerebral artery
Pontine branches
Basilar artery
Vertebral artery

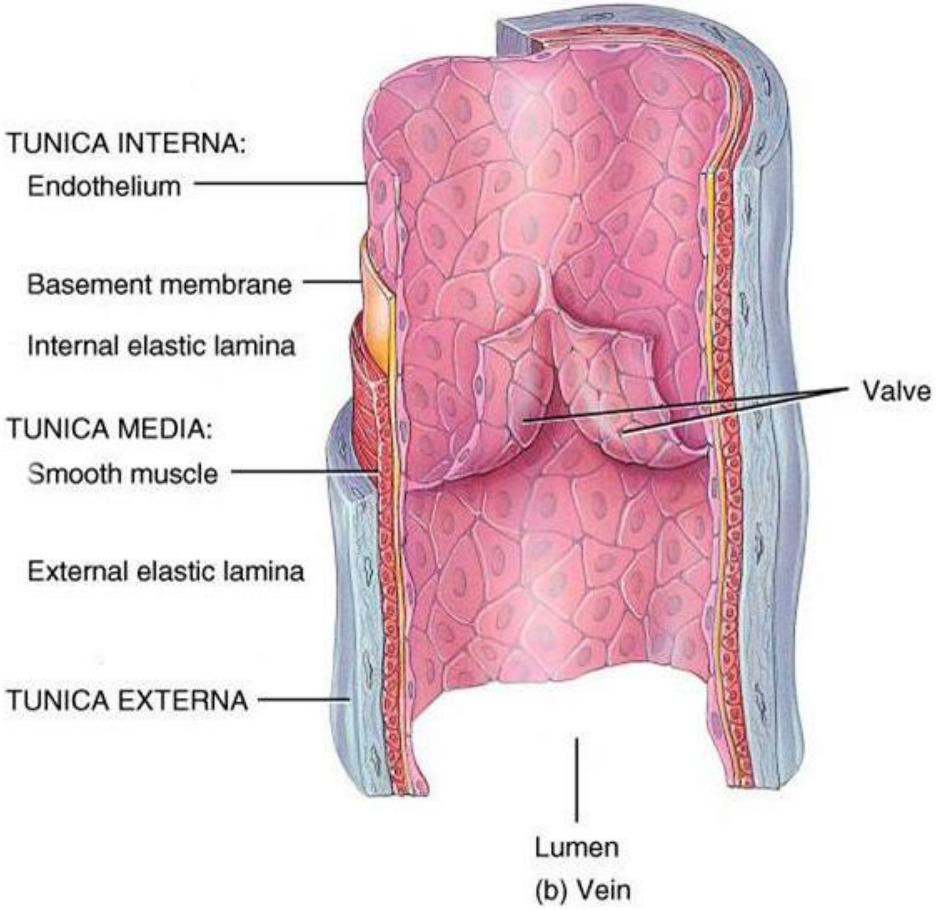
Aorta

- Largest artery
- Branches lead to all the organs of the body, supplying them with oxygen and nutrients.



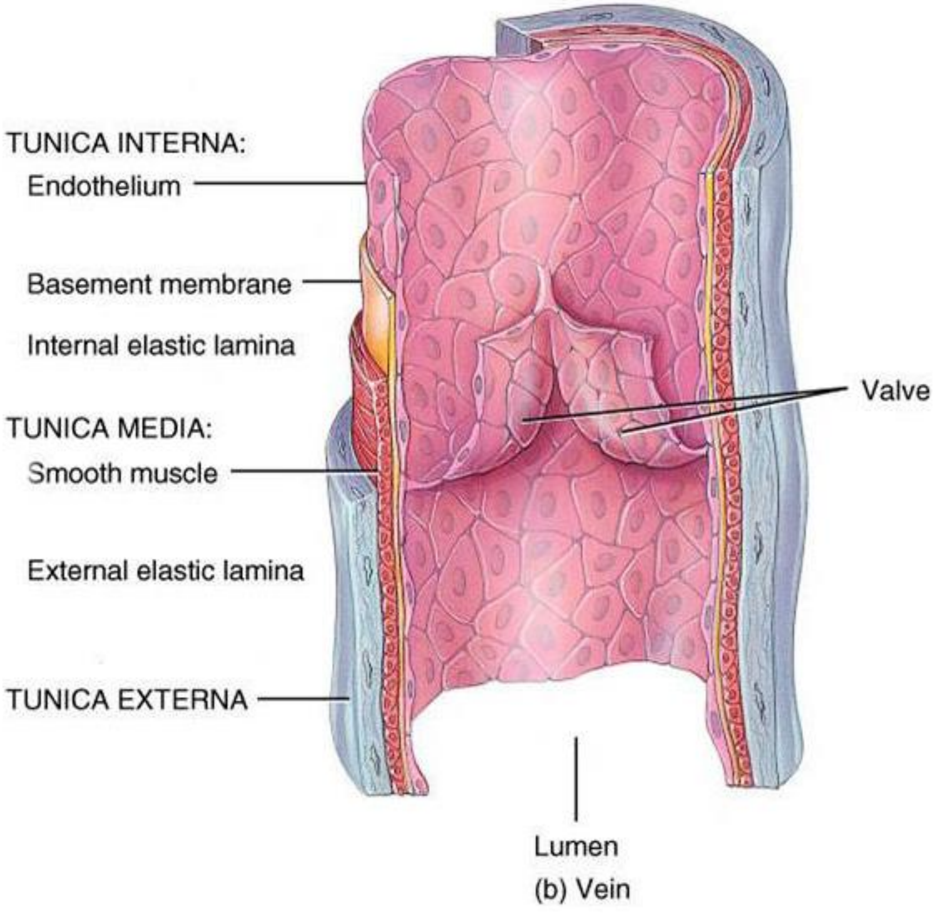
Veins

- Carry blood towards the heart
- Typically contains deoxygenated blood
- Leaving capillaries, it enters venules and enlarges to form veins
- Are less rigid so can hold more blood (70% of total volume)



Veins

- Operate on the low-pressure side of the system
- Have thinner walls than arteries
- Less capacity to decrease their diameter
- Backpressure
- Usually carry oxygen-poor blood to the heart

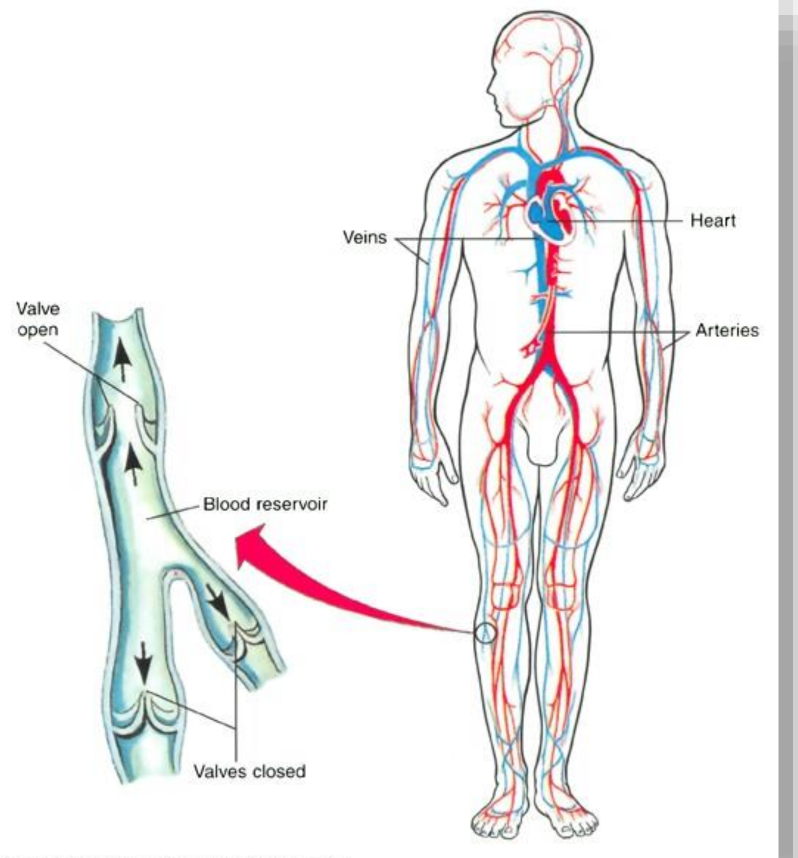


Veins

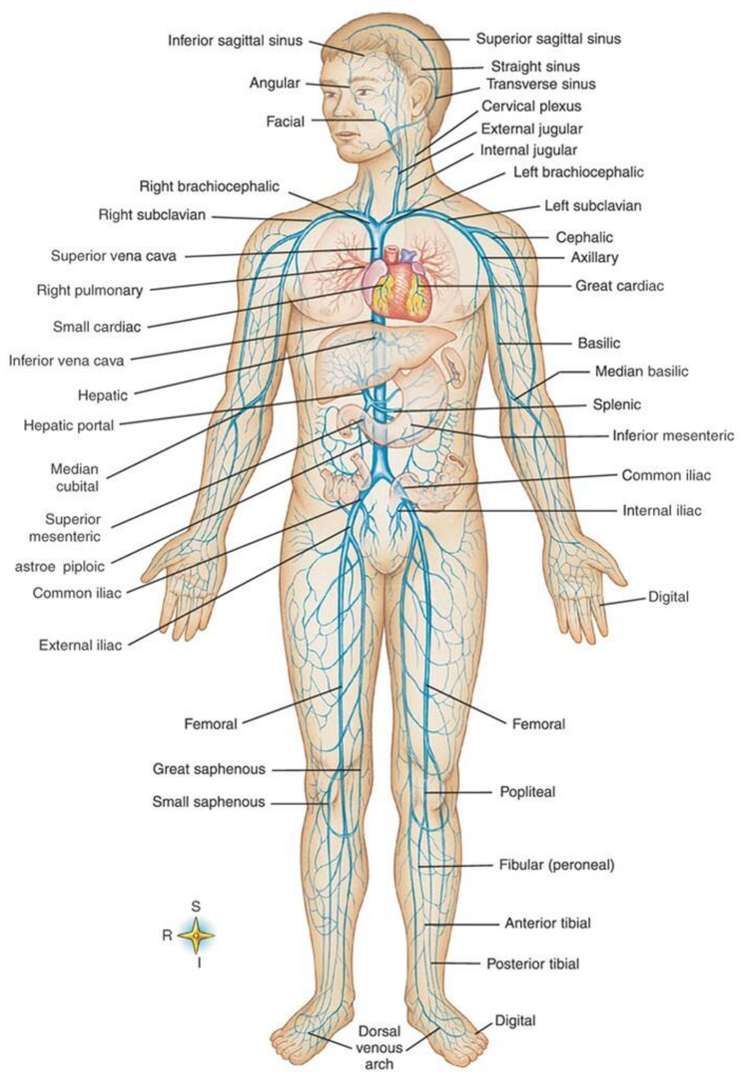
- 3 Layers
  - Inner
    - Tunica Intima (tunica interna)
    - Endothelium cells produce semi-lunar valves
  - Middle
    - Tunica Media
    - Smooth muscle layer (thinner than arteries)
  - Outer
    - Tunica Externa (tunica adventitia)

Venous Blood Reservoir

- Have great capacity to stretch (capacitance)
- Allows for accommodation of large amounts of blood with NO change in BP
- Allows for venous circulation based on pressure from valve below

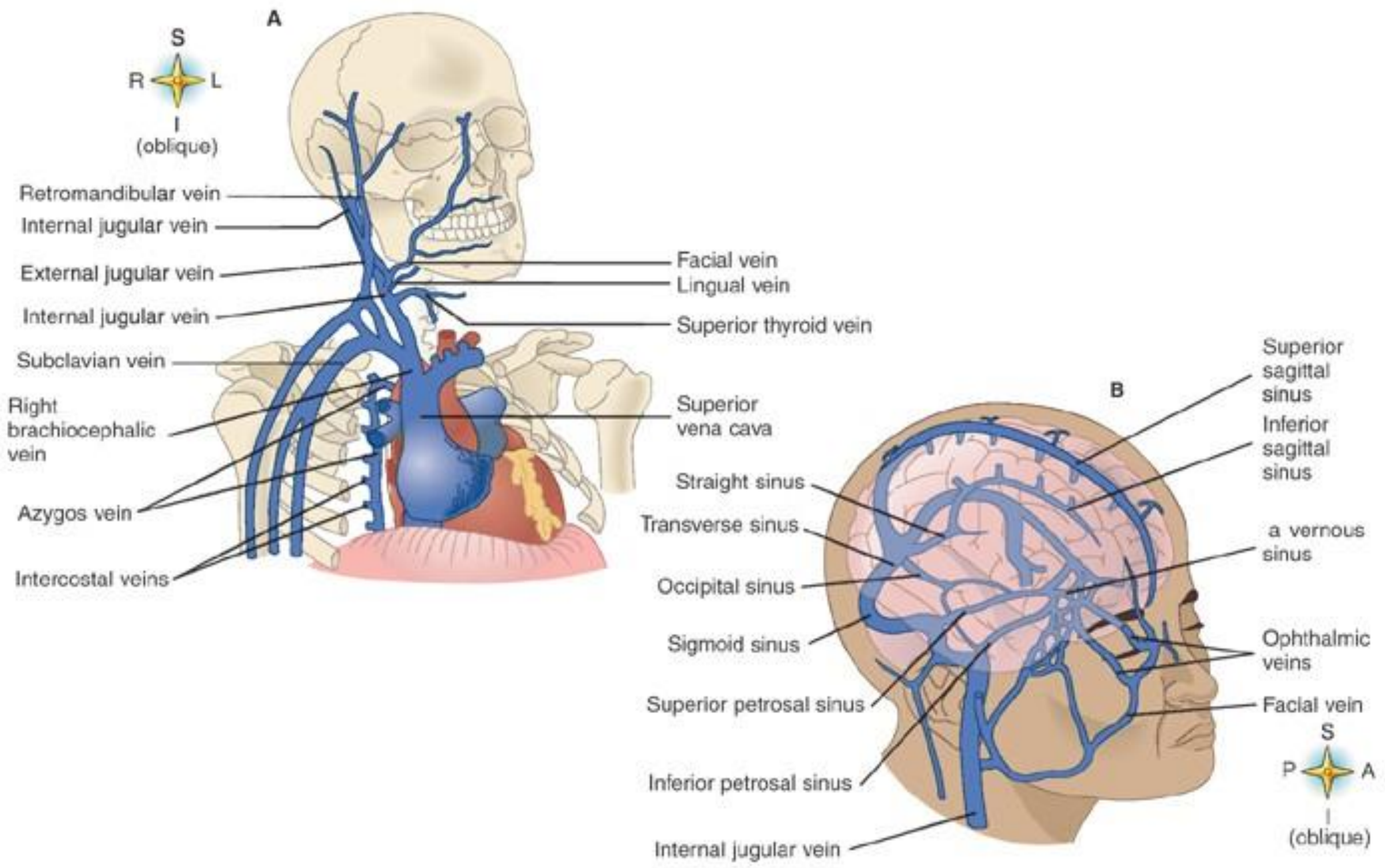


Veins



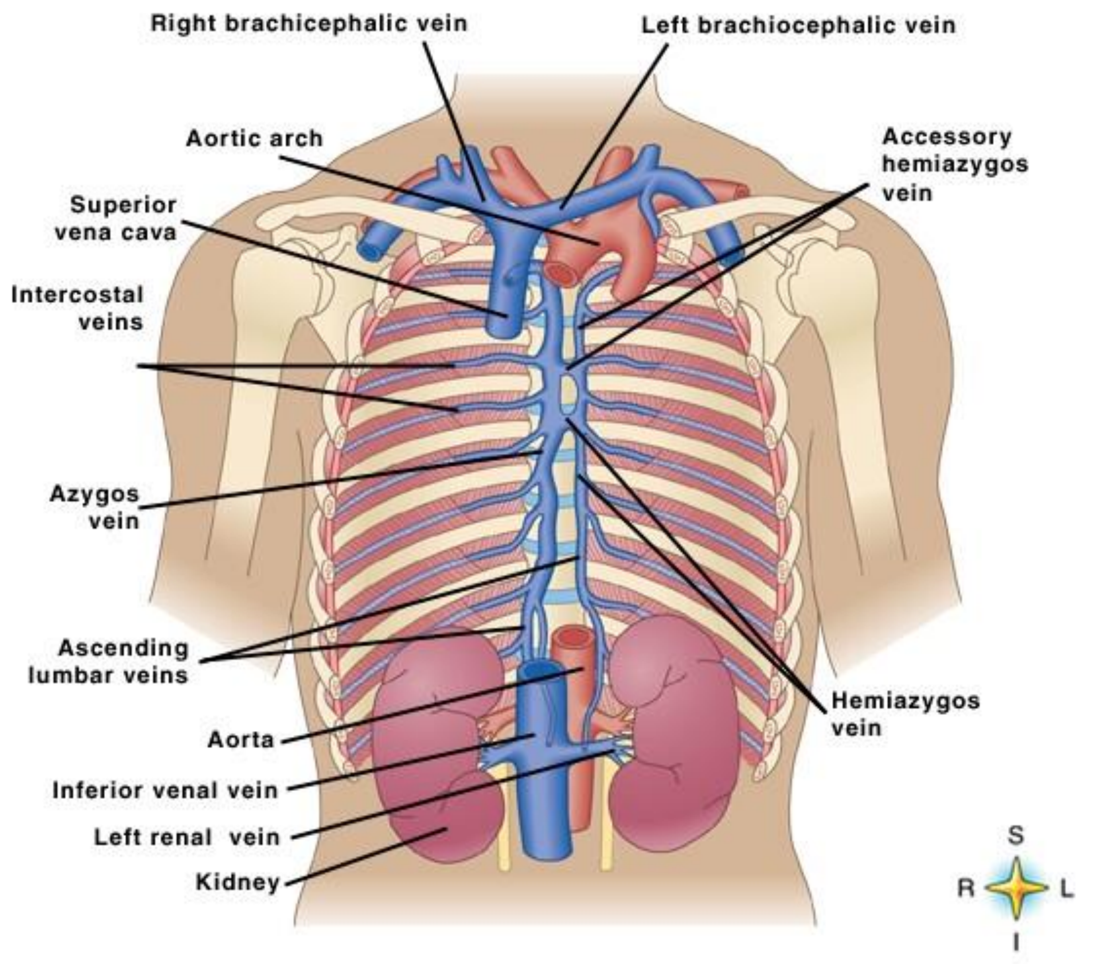
Inferior sagittal sinus
Superior sagittal sinus
Straight sinus
Transverse sinus
Angular
Cervical plexus
Facial
External jugular
Internal jugular
Left brachiocephalic
Right brachiocephalic
Left subclavian
Right subclavian
Cephalic
Superior vena cava
Axillary
Right pulmonary
Great cardiac
Small cardiac
Basilic
Inferior vena cava
Median basilic
Hepatic
Splenic
Hepatic portal
Inferior mesenteric
Median cubital
Common iliac
Internal iliac
Superior mesenteric
astroe piploic
Common iliac
Digital
External iliac
Femoral
Femoral
Great saphenous
Popliteal
Small saphenous
Fibular (peroneal)
S
R
I
Anterior tibial
Posterior tibial
Digital
Dorsal venous arch

Veins

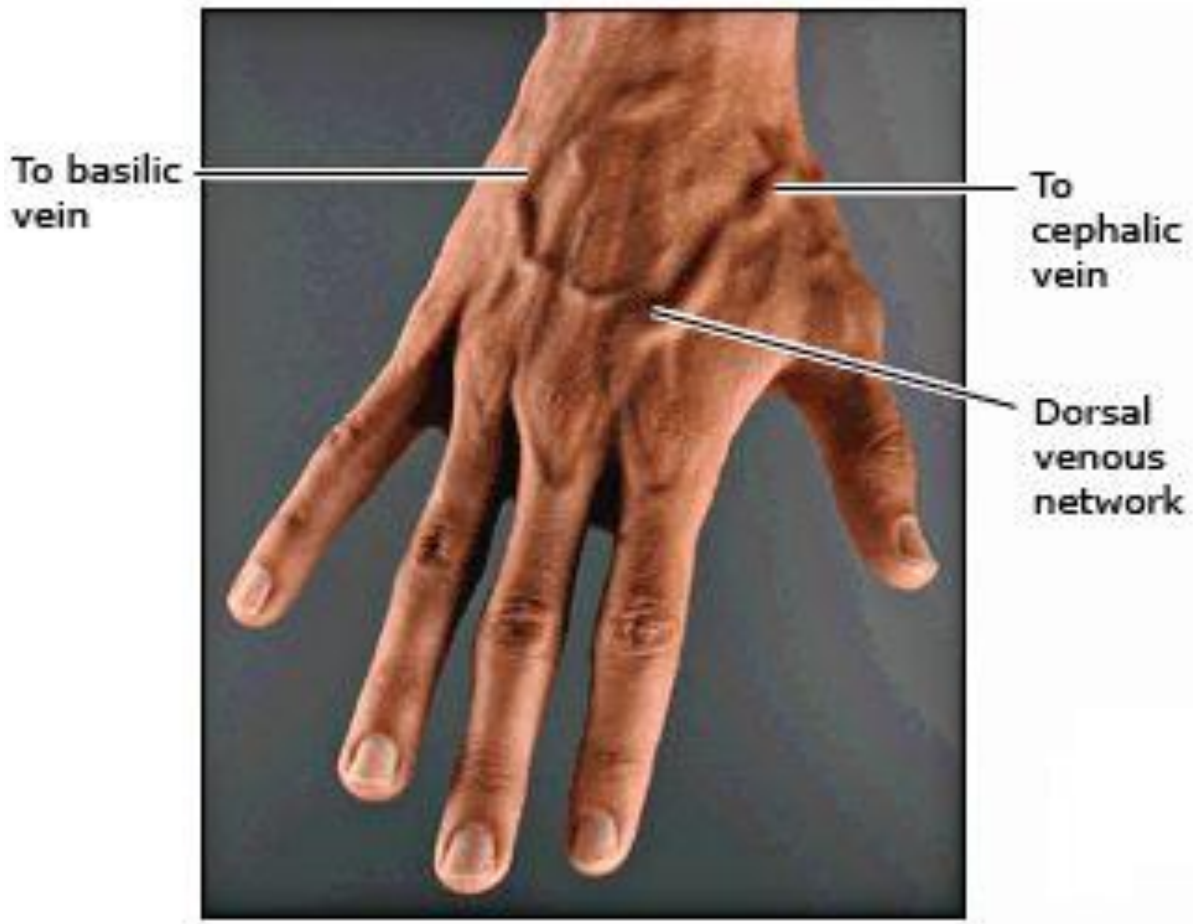


A
S
R
L
I
(oblique)
Retromandibular vein
Internal jugular vein
External jugular vein
Internal jugular vein
Subclavian vein
Right brachiocephalic vein
Azygos vein
Intercostal veins
Facial vein
Lingual vein
Superior thyroid vein
Superior vena cava
B
Straight sinus
Transverse sinus
Occipital sinus
Sigmoid sinus
Superior petrosal sinus
Inferior petrosal sinus
Internal jugular vein
Superior sagittal sinus
Inferior sagittal sinus
a vernous sinus
Ophthalmic veins
Facial vein
S
P
A
I
(oblique)

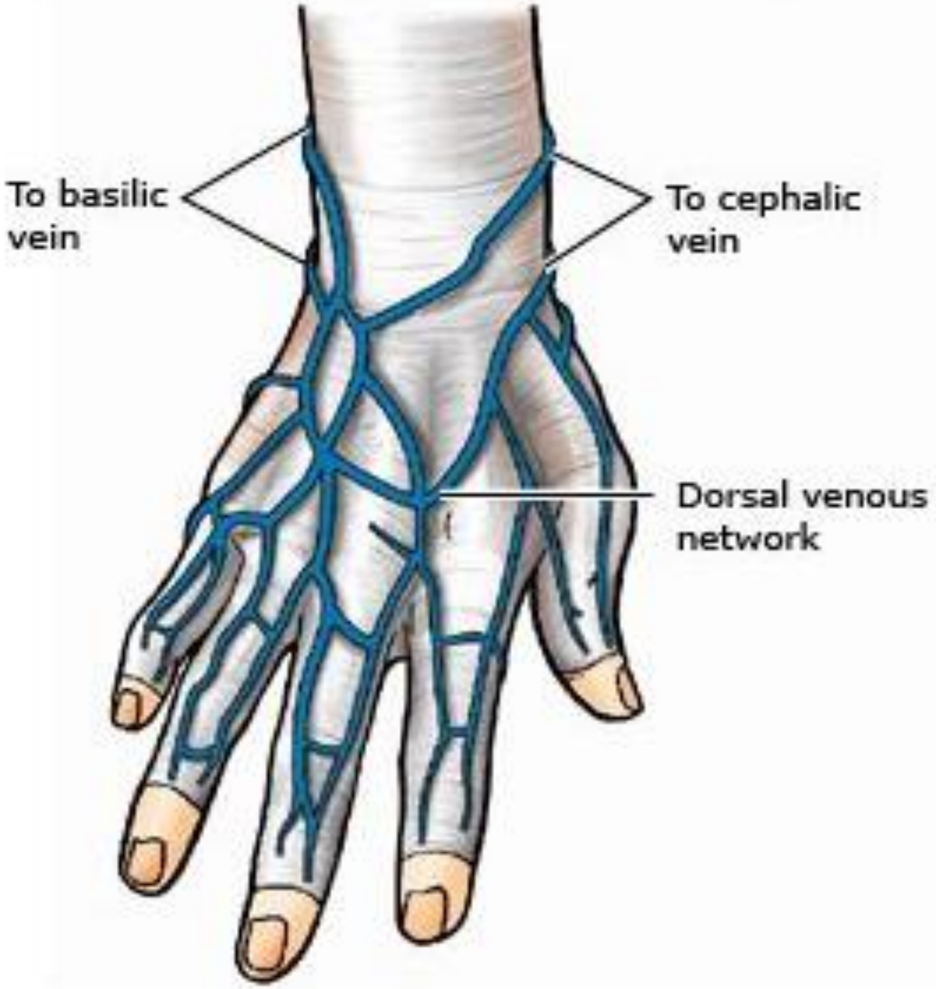
Veins


Right brachicephalic vein
Left brachiocephalic vein
Aortic arch
Accessory hemiazygos vein
Superior vena cava
Intercostal veins
Azygos vein
Ascending lumbar veins
Hemiazygos vein
Aorta
Inferior venal vein
Left renal vein
Kidney
S
R
L
I

Veins

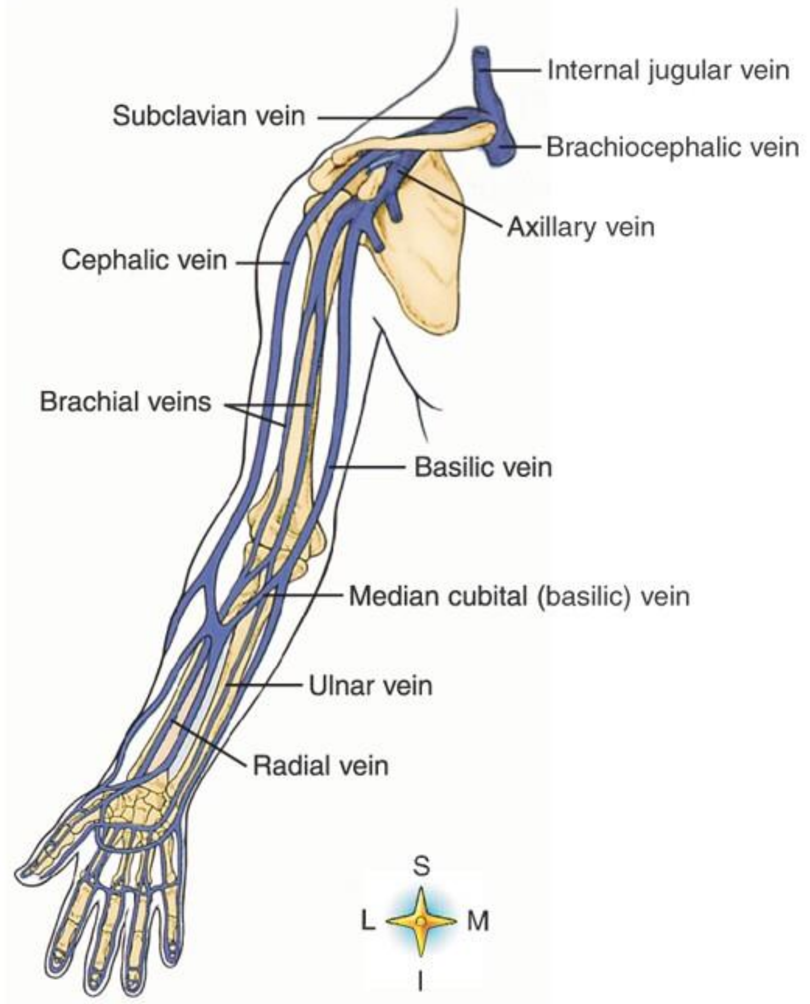


To basilic vein
To cephalic vein
Dorsal venous network



To basilic vein
To cephalic vein
Dorsal venous network

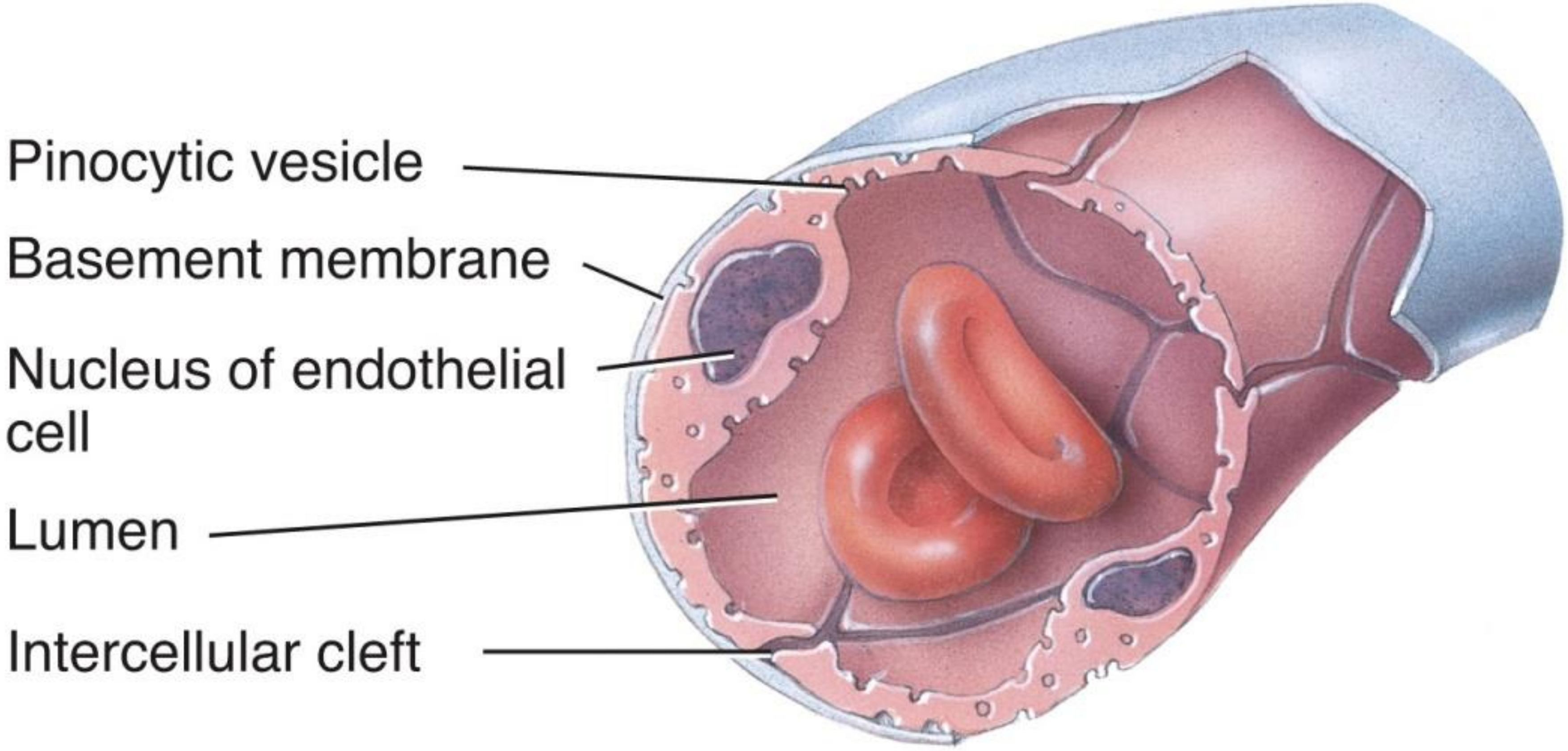
Veins


Internal jugular vein
Subclavian vein
Brachiocephalic vein
Axillary vein
Cephalic vein
Brachial veins
Basilic vein
Median cubital (basilic) vein
Ulnar vein
Radial vein
S
L
M
I

Capillaries

- Smallest and most numerous
    - Contain about 5% of total volume
- Are the connection between the arteries to the veins
    - – Network of microscopic vessels between the tiny arterioles and venules
- Are composed of only the endothelium
    - – Extremely thin wall
    - – Enables the exchange of gases and nutrients
    - – Diameter is so small that red blood cells must pass through single file.
- Distribution is based on metabolic needs
    - Liver, muscle, kidneys have extensive network
    - Epidermis, lens and cornea have none

Capillaries

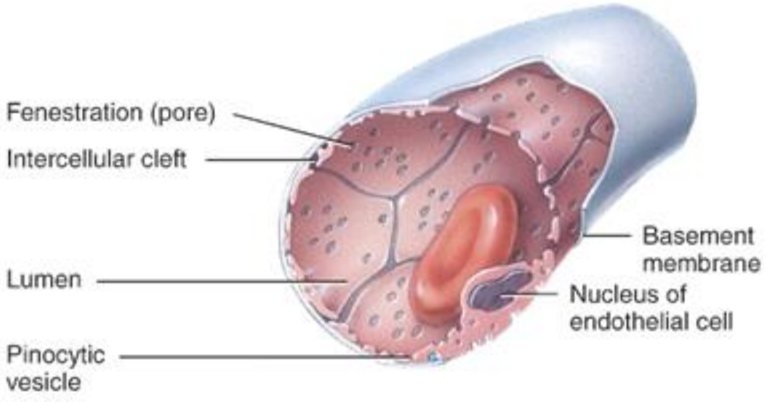


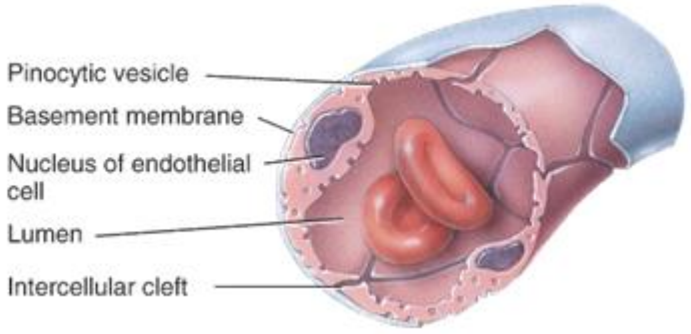
(a) Continuous capillary formed by endothelial cells

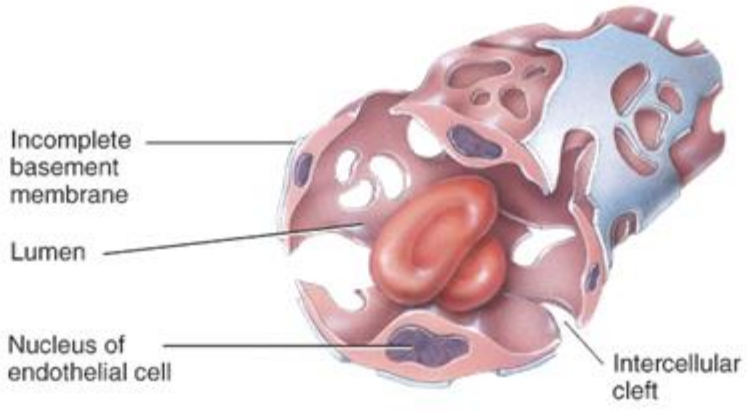
Vessel Structure and Function

- The body contains three types of capillaries:
  - Continuous capillaries are the most common with endothelial cells forming a continuous tube, interrupted only by small intercellular clefts.
  - Fenestrated capillaries (fenestra = windows), found in the kidneys, villi of small intestines, and endocrine glands are much more porous.
  - Sinusoids form very porous channels through which blood can percolate, e.g., in the liver and spleen.

3 Types of Capillaries







Fenestrated

- Found in organs and glands that require a continuous exchange of blood such as:
  - Kidneys
  - Small intestines
  - Pancreas
  - Endocrine glands

Continuous

- Most common type
- Small gaps allow for exchange of gases, water, glucose and some hormones to pass through

Sinusoid

- "Leakiest" type allowing for exchange of large molecules and cells
- Can be found in the liver, spleen, bone marrow

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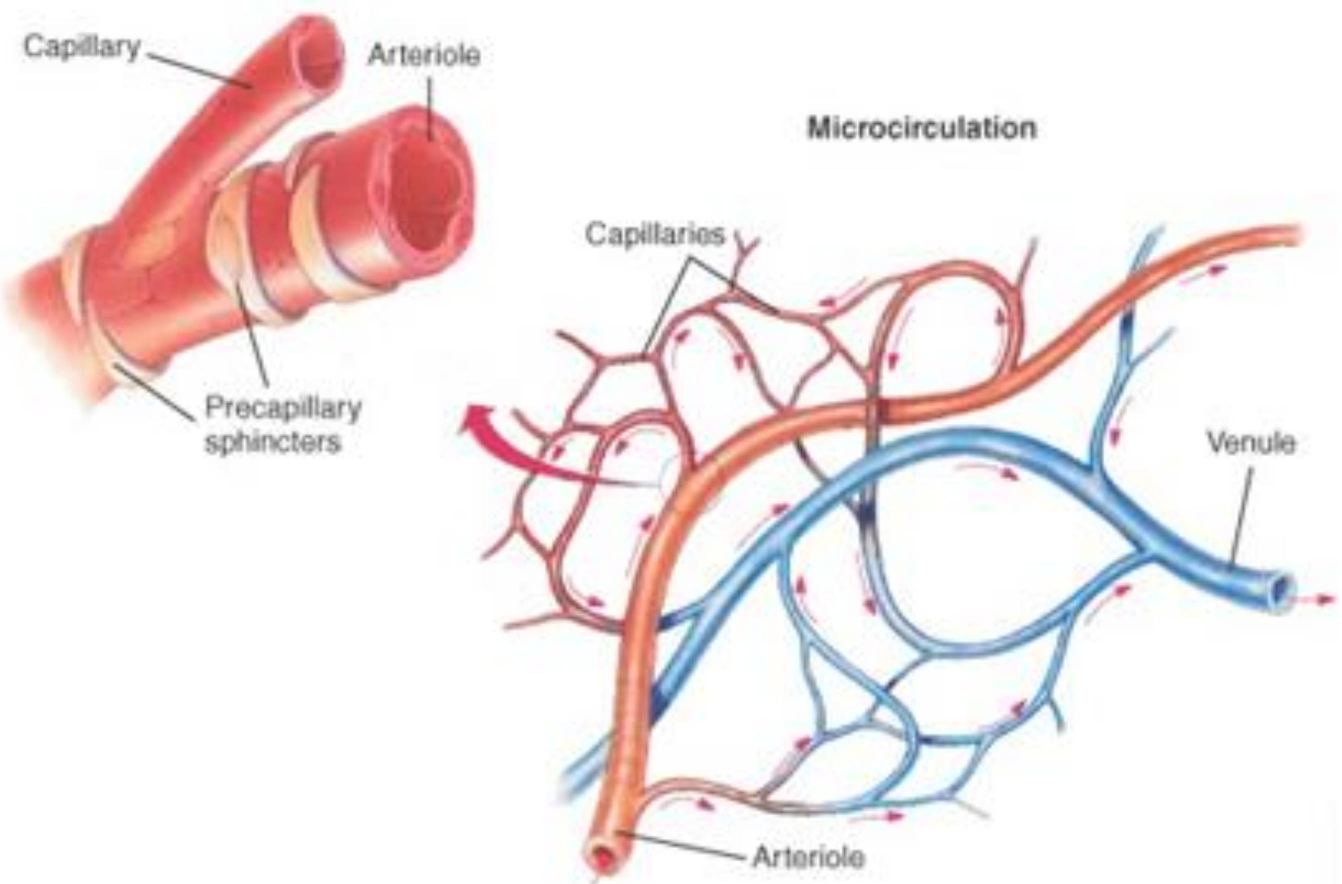
Capillaries

- Have vital role in exchange of gases, nutrients and waste between blood and tissue
  - Thin wall (one cell thick) with fenestrations
  - Provide the slowest flow rate of blood in the system
  - Tissues are surrounded by extracellular fluid called interstitial fluid
- Blood flow into capillaries is regulate by smooth muscle (pre-capillary sphincters)
  - If constricted blood is directed through metarterioles (arteriovenous anastomoses or AV shunts)

Capillaries

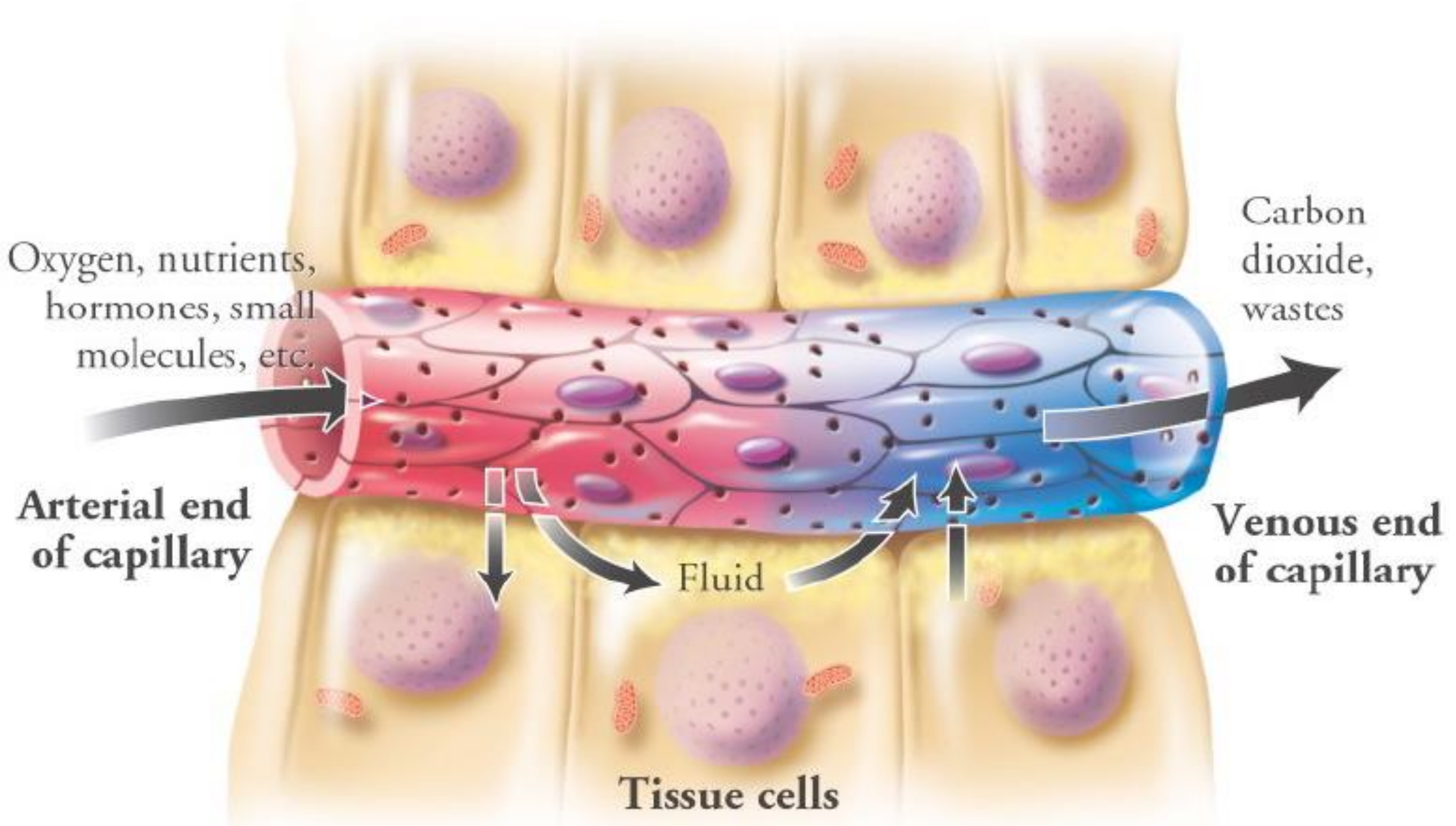
- This is known as Capillary Microcirculation
  - **90%** of fluid is returned to system
  - **10%** collected by lymphatic vessels and returned to circulation in venous blood



Factors Affecting Movement

- Net Filtration (Starling's law of the capillaries)
- Net filtration = forces favoring filtration vs. forces opposing filtration
  - Forces favoring filtration
    - Blood Hydrostatic pressure (BHP)
    - Interstitial fluid colloid osmotic pressure (IFCOP)
  - Forces opposing filtration
    - Blood Colloid Osmotic pressure (BCOP)
    - Interstitial fluid hydrostatic pressure (IFHP)
  - Other factors
    - Tonicity
    - Membrane permeability

Factors Affecting Movement

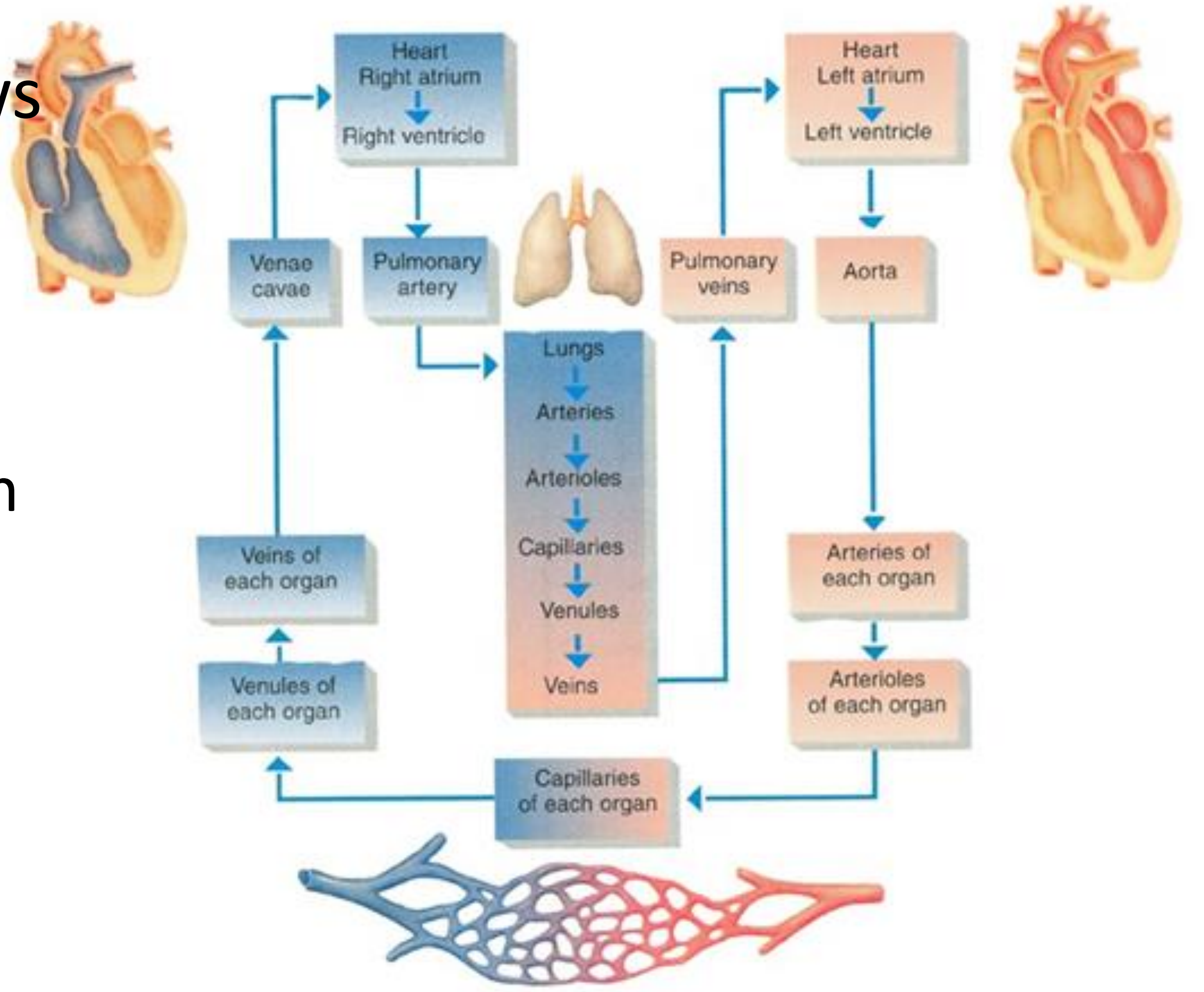


Blood Flow

- Is the movement of blood through the body
- Moves from an area of high pressure to an area of low pressure
- Highest pressure
  - with systolic contraction of heart
- Lowest pressure
  - found in vena cava as it enters the R atrium (pressure in R atrium is also known as central venous pressure)

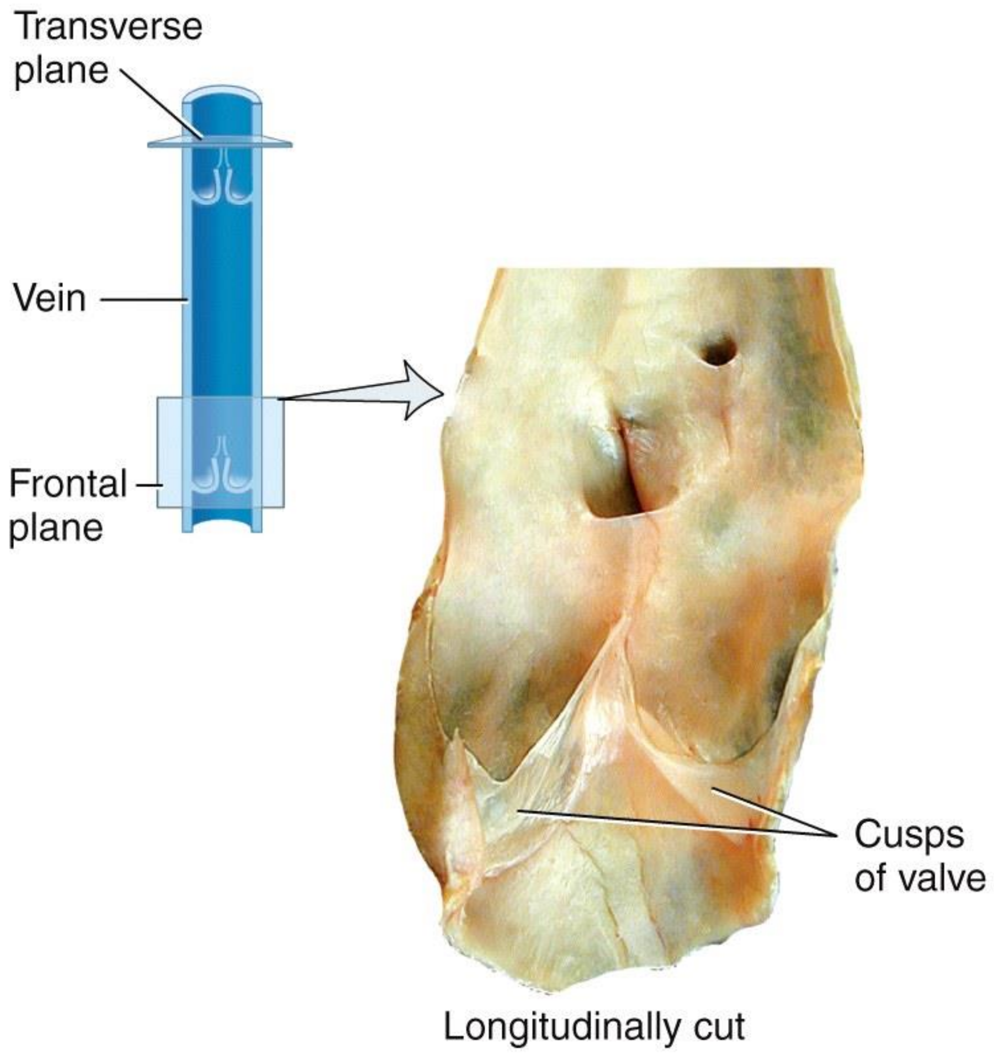
Blood Velocity

- Is the rate at which blood flows
- Varies depending on size of vessel
  - Is greatest in aorta and decreases as vessels decrease in size
  - Slowest in capillaries
  - Regains some speed as enters venules and veins



Venous Return

- The volume of blood returning through the veins to the right atrium must be the same amount of blood pumped into the arteries from the left ventricle – this is called the venous return.



Venous Blood Flow

- Very little pressure in veins
- Venous return is dependant on:
  - Muscle action
    - Muscle contracts, thickens and squeezes veins next to it
  - Respiratory movements
    - As diaphragm contracts changes thoracic pressure causing abdominal blood to move
  - Contraction of veins
    - Sympathetic reflexes cause constriction

Venous Return

- The skeletal muscle pump uses the action of muscles to move blood in one direction (due to valves).
- The respiratory pump uses the negative pressures in the thoracic and abdominal cavities generated during inspiration to pull venous blood towards the heart.